

A Study of Retroactive Inhibition

BY
J. EDGAR DECAMP, A.M.

A THESIS
SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN THE
UNIVERSITY OF MICHIGAN

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MONOGRAPHS

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A. ORIGIN OF THE PROBLEM

Since the rather exhaustive work of Müller and Pilzecker, investigating various aspects of memory, Retroactive Inhibition¹ has held an unquestioned place among the principles of Psychology. It follows naturally that it may play an important part in our mental activities. Undoubtedly, it is to be considered in the construction of any system for the attainment of the highest efficiency in learning for recall, with the least expenditure of mental energy. Furthermore, it seems in accordance with popular science, and with a certain scientific tendency towards the assertion of the unification of both mental and physical energy, that if, after studying one task, the attention is turned to a second task immediately upon the completion of the first, the first task will not have the same recall value as if the second task had not succeeded the first.

At the beginning of this work the author took these conclusions as well grounded and, sharing the consensus of opinion among psychologists that the effect of retroactive inhibition is quite marked under certain conditions, proceeded upon this basis. In the work of Müller and Pilzecker the existence of retroactive inhibition was seemingly definitely established. However, into a consideration of its various aspects they did not enter. It seemed, then, of scientific value to know the more minute details of the workings of this process. In carrying out this work, it was the author's purpose to investigate the nature of the working of retroactive inhibition, to produce curves evidencing its relative influence with the lapse of time subsequent upon learning, to consider the nature of these curves, and to note important subsidiary phenomena as they might appear in the course of the experiment.

¹For convenience of expression, the writer deals with retroactive inhibition, throughout this paper, as if it were really defined as an *active* mental process, rather than as an *effect* of some activity upon the permanence of a closely preceding activity.

The experimental work upon this problem was begun in the summer of 1912. The work done at that time, though bearing out the general conclusions of this paper, is not considered sufficiently accurate and exhaustive to serve as a base for any definite conclusions; the development of a more accurate method being its chief service. The work upon which our conclusions are based was carried out in the school years 1912-'13, 1913-'14, and the summer of 1913. In Experiments I to XII seven subjects—six men and one woman—were used. In Experiments XIII 34 subjects—eleven women and twenty-three men—were employed.

B. WORK OF OTHERS—LITERATURE

From 1892 to 1900 Müller and Pilzecker, two German investigators, continued the work on memory, begun some years previously by Müller and Schumann. They conducted a series of forty experiments, endeavoring to bring out the main laws of association and inhibition as they appear in connection with the learning of nonsense material. Their report of these experiments appeared in the *Zeitschrift für Psychologie*, 1900, *Ergänzungsband* 1. Their work is an example of untiring effort in the quest for knowledge. We are indebted mostly to them for our present conception of the Perseveration Tendency, Generative, Effectual, and Retroactive Inhibition. It is the last, Retroactive Inhibition, which forms the main subject of our discussion in this paper. Closely related to our phase of the memory problem they conducted nine experiments, (Versuchsreihen 29 to 37). The general tenor of their method in these experiments is as follows:

The subject is shown a series of twelve nonsense syllables, written on a strip of paper, and placed around a twelve-sided prism in such a way that a syllable corresponds to each of the twelve sides of the prism. This prism is revolved behind a metal screen, containing an adjustable slit through which the subject may view the syllables as they pass on the revolving cylinder. The syllables are repeated a certain number of times in trochaic rhythm. The number of repetitions for any experiment is kept constant. The variability of the experiment lies in the arrange-

ment of the mental activity of the subject during the interval between the learning and the test. This interval, for simplicity of explanation, may be divided into three parts, (1) a rest, (2) mental activity, usually consisting of an after-series (Nachreihe), *i.e.* the attention is turned to the learning of a new series of syllables, and (3) a second rest period. Then follows the test. For testing the syllables, the apparatus mentioned above, together with a Hipp chronoscope and lip-key, or sound-key (Schalltrichter), are introduced into an electric circuit. The chronoscope is adjusted for running with a broken circuit. A slide, to hide the syllable from the subject's view, is held in front of the slit by means of an electro-magnet just above it. The operator breaks the circuit, allowing the slide to fall, thus exposing the syllable to be tested. With the fall of the slide the chronoscope starts. The subject reacts with what he thinks to be the corresponding unaccented syllable. If he does not know, he replies "Nichts." A brief outline of eight of the nine experiments (Versuchsreihen 29 to 37) follows. The other, because of its important bearing upon the problem in hand, is given *in toto*.

Experiments 29 and 30:

The purpose of these two experiments was a comparison of 24-hour and 11-minute associations. Little more was accomplished than a mere notice by one of the subjects that employment during the rest interval, after learning a set of syllables, injured the associations of these syllables. The numerical results showed nothing of particular importance.

Experiment 31:

In this experiment a comparison was made between series learned with no mental activity closely following, and series learned with the learning of a second series following 34.4 seconds after the completed learning of the first. In the first case the average success was 48 per cent, with the average time for successful scores 2480σ. The corresponding figures for the other case were 23 per cent and 3570σ. The number of accented syllables shown in the test was 144.

(For brevity the following symbols are brought over from Müller and Pilzecker's work. H(Hauptreihe), a series learned for test. N(Nachreihe), a series learned soon after the learning of an H series. V(Vergleichsreihe), a series with no N series following its learning; r , the per centum of successes; T_r , the average time for the successes; n , the total number of syllables tested in any particular experiment.)

Experiment 32:

The general plan was the same as that of Experiment 31. The reading of the N series was begun 17.8 secs. after learning an H series. The results, $n = 162$, were: For the H series; $r = 27$ per cent, $T_r = 3230\sigma$; For the V series; $r = 55$ per cent, $T_r = 3070\sigma$. The subject indicated that he would rather not look at a newspaper, for it would make him forget his syllables. He found the best way to employ his time was to walk up and down the room, and give himself up to meditation.

Experiment 33:

Plan of Experiment 32. The reading of the N series was begun 27 secs. after the reading of the H series. The experiment was discontinued after eight days, "*weil die rückwirkende Hemmung in unbestreitbarer Weise hervorgetreten war und eine weitere Fortsetzung der Versuche überflüssig erschien.*" For the H series; $r = 43$ per cent, $T_r = 2260\sigma$. For the V series; $r = 72$ per cent, $T_r = 2090\sigma$. ($n = 72$).

Experiment 34:

This experiment was designed to compare two kinds of series, and H_1 series, where the N series followed after 17.2 secs., and H_2 series, where the N series followed after six minutes. The accented syllables of the H_1 and the H_2 series were mixed and tested after one and one-half hours. Results: For the H_1 series; $r = 28$ per cent, $T_r = 2760\sigma$. For the H_2 series; $r = 49$ per cent, $T_r = 3000\sigma$. ($n = 144$).

The subject stated that it was better not to busy herself with a magazine during the rest period, for she had previously noticed that such activity was injurious to the recall of the syllables. It was best to allow the thoughts to wander where they would.

Experiment 35 (*in toto*.¹)

This experiment, in which Dr. Behrens acted as subject, was conducted in the same way as Experiment 32, in which Dr. Behrens was the subject, with the exception of the unimportant circumstance, that the main series (*Hauptreihe*) and the comparison series (*Vergleichsreihe*) were not read twelve times but, on account of the acuteness of the subject, were read only eight times; and with the exception of the very important circumstance that the mental activity of the subject, following the reading of the main series, did not consist in the reading of a second series of syllables. The subject had, directly after the reading of each main series, to observe attentively three different landscape pictures that had been previously prepared for the purpose, and, directly after the observation of all three pictures, to describe, as nearly correctly as possible, to the operator what he had seen in each picture. The time of observation for each picture lasted ten seconds. To be sure, a picture once used was never used again in the experiment. In order that the consideration of, and the meditation on, the pictures might not leave behind any fatigue of the subject for the test of the just previously read syllables of the main series, the work with the pictures never extended over a longer interval than two minutes, so that, if the subject had not finished the picture work after a lapse of two minutes after completing the reading of the main series, he was stopped after this period without further ado. Between the picture work and the test of the accented syllables of the main series there always occurred a rest period of at least six minutes. The experiment was discontinued after twelve days for the expected result was obtained in an unquestioned way. The main series, whose readings the picture work followed, gave with each temporal position many less successes and fewer very small times than the comparison series which were not followed by picture work. On the whole, $n = 108$, there resulted:

For the H series; $r = 24$ per cent, $T_r = 2950\sigma$

For the V series; $r = 56$ per cent, $T_r = 2490\sigma$.

¹ Free translation.

If one compares these results with those received in Experiment 32, it appears that in this experiment with picture work, at least as strong an injurious influence upon the associations was at work as that which existed in Experiment 32 through the 12-time reading of the after series. We hasten to remark that, before the beginning of this experiment, we knew, through occasional experiments, Dr. Behrens might possess a strong interest and concentrated attention with visual pictures. It does not necessarily follow, that other subjects, in experiments arranged as ours, may not give less striking results.

Experiment 36:

The savings method was used with the learning of another set of syllables for the mental activity following the learning of the main series. Results in two cases were obtained, ($n=32$):

An H series, requiring an average of 13 repetitions.

A V series, requiring an average of 11.25 repetitions.

An H series, requiring an average of 7.8 repetitions.

A V series, requiring an average of 6.6 repetitions.

Experiment 37:

The savings method was used. As in Experiment 35 pictures were used for influencing the fixity of the associations of the previously learned series of syllables. Results, $n = 24$:

An H series, requiring an average of 8.0 repetitions.

A V series, requiring an average of 4.9 repetitions.

Conclusions of Müller and Pilzecker (abridged):

1. The introspections of the subjects indicate retroactive inhibition.
2. The numerical results of Experiments 31 to 37 indicate retroactive inhibition.
3. Retroactive inhibition is the greater the more attention paid to the interpolated work.
4. Retroactive inhibition is much weaker when the interpolated work is done after six minutes than when it is done immediately after learning.
5. That the work precludes thinking of the syllables does not explain retroactive inhibition.

6. The results obtained are not due to the similarity of the syllables of the N series to those of the H series.

7. The influence of fatigue, following the work, was eliminated.

8. The work did more than merely to weaken the condition of preparedness.

9. Physiological activity continues after reading. This is weakened by any other activity.

10. The processes underlying retroactive inhibition and the perseveration tendency are the same.

11. The objection that, because of the perseveration tendency, the associations should increase, is not valid.

12. The condition of preparedness between the first and the eighth syllables is different from that between the first and second, for the brain excitations are different.

13. The application to didactics is clear.

At the Fifth International Congress for Experimental Psychology,¹ 1912, G. E. Müller made a brief report of an investigation which was then being carried on by Frl. Heine, who was working under the direction of Professor Müller. Her results with nine subjects indicated that retroactive inhibition does not apply to the process of Recognition, when tested with nonsense syllables. Four of the subjects were tested for retroactive inhibition, according to the method used by Müller and Pilzecker. The average percentages of the four tests for the Hauptreihen and the Vergleichsreihen were 22 per cent and 38 per cent respectively.

Müller remarked that, from the results obtained, it appeared retroactive inhibition manifested itself less easily as more repetitions were given the series in the learning process.

Other than the work of Müller and Pilzecker and that of Frl. Heine, the writer is unaware of any important work done upon the subject of retroactive inhibition. As noted by Müller and Pilzecker and by Müller, a few investigators, Bigham, Von Kries, E. Meyer, in experiments with different purposes in view, have made mention of results, more or less harmonizing with

¹ Vide *Bericht über den V. Kongress f. exper. Psychologie*, 1912, S. 216 ff.

the idea of retroactive inhibition. Bigham,¹ in the presentation of numbers, colors, forms, syllables, etc., noticed more errors after an attention-engaged interval, and remarked, "The filling of the intervals hinders the memory." Von Kries² remarked, that the memory of a seen extent fades very quickly, if the time following the perception of the extent is filled with some other activity.

Some of the recent texts on Psychology call attention to retroactive inhibition. Pillsbury,³ in his *Essentials*; Meumann,⁴ in his book on memory; and Myers,⁵ in his brief summary of the work done on memory, allude to its existence. Ebbinghaus⁶ refers to it as a possible explanation for the disproportionate increase in the number of repetitions required as the "memory span" is exceeded.

C. APPARATUS

The apparatus used in the majority of these experiments may conveniently be divided into three parts.

I. A modified form of the Wirth card-exposure apparatus. This apparatus was modified and used by Dr. J. F. Shepard and H. M. Fogelsonger in their work on Inhibition. In their article reference is made to the main modification.⁷ For clearness the modifications there introduced may be briefly described. In place of the cylinder with stationary electrical contacts, an all-metal cylinder, with adjustable contacts, was substituted. Around the cylinder, and beneath a surface shell, were placed fourteen sliding strips, each strip bearing a metal contact point projecting through a narrow groove in the surface shell. By adjusting these strips, any number of the fourteen points can be arranged so that contact with the insulated projecting brush will be made as the cylinder revolves. Midway between two strips was soldered,

¹ Cited from Müller and Pilzecker's articles, S. 194.

² Cited from Müller and Pilzecker's article, S. 194.

³ *Essentials of Psychology*, 1913, p. 196.

⁴ *The Psychology of Learning*, English translation, 1912, p. 147.

⁵ *Text-book of Experimental Psychology*, 1911, Pt. I, p. 153 f.

⁶ *Grundzüge der Psychologie*, 1902, S. 652.

⁷ *Psychological Review*, Vol. XX, (No. 4, July, 1913, p. 292.

along its middle line, leaving its edges free, a thin and narrow strip. This resulted in fourteen grooves, directly over the fourteen sliding strips, which serve to hold strips of paper bearing syllables for the exposure. This modification greatly facilitated the manipulation of the syllables.

A second modification consisted in the addition of a clutch to take the place of the cumbersome link-chain part. In using the link-chain, when more than a certain number of revolutions of the cylinder were required, the operator had to stop in the midst of the presentation process until the chain could be re-adjusted. With the clutch, all that is necessary, when the weight runs down, is to gently pull the end of the cord bearing the counterweight. The regularity of the revolution of the cylinder is not altered, and the distraction of the subject, due to the change, is negligible.

A further and minor modification was the addition of a metal projection to each of the two ratchets, thereby enabling the cylinder to be easily tripped with the fingers, when it is not desired to use the electric circuit and metronome for tripping.

2. A Hipp chronoscope for registering time.

3. A mouth-key. The mouth-key served as a reaction part for breaking the electric circuit upon the subject's receiving the stimulus word. This apparatus consists of a circular metal box, somewhat similar to a frustum of a cone, the small end of which contains an opening. The sides of this opening are shaped to fit snugly about the nose and mouth. Absorbent cotton was used about the edges to render the box air-tight when fitted against the face. The opposite end of the box contains a single circular opening with a projecting band. Over this opening is placed a rubber tambour. To the tambour is waxed a disk to which is pivoted an aluminum pointer, one end of which is pivoted to a post on the side of the box. For the other end of the pointer there is an insulated post upon which the free end of the pointer may rest. Adjacent to the insulated post is a second post in connection with the box itself. These posts are fitted for wire connection. The working of the instrument is

as follows: When the mouth and nose are placed in the opening, the face pressed closely against the edges of the box, and a word spoken, the air pressure forces the tambour outward, consequently pushing the pointer off its post, thereby breaking the circuit.¹

A simple metronome for regulating the rate of exposure of the syllables and a commutator complete the list of apparatus.

The complete set-up may be diagrammatically represented thus, Fig. 1.

M. K., mouth-key; C., commutator; W. C. A., Wirth card-exposure apparatus (modified); H. C., Hipp chronoscope.

The working of the combined apparatus, in a test, may be briefly mentioned. The syllables to be tested are placed on the cylinder of W. C. A. in alternate grooves. One of the two slides closing the exposure slit should be pulled up, allowing the subject to see the first syllable of each pair of syllables as the cylinder revolves. With the exposure of each test syllable contact is made at W. C. A. Upon thinking of a suitable response, the subject speaks into M. K. We then have the time elapsing between the exposure of the test syllable and the subject's reaction thereto.

¹ The mouth-key was designed by Dr. Shepard for reducing, as far as possible, the time elapsing between the subject's thought of a response and his actual response as indicated by the apparatus. The lip-key is open to the objection that the quickness of its release may vary with the response-word. In fact, a clear enunciation of some words does not necessarily require its release.

The sound apparatus has the objection that for its use a relay must be inserted. This latter instrument increases the inertia to be overcome and movement to be made, both requiring time. The mouth-key is scarcely open to either of these objections. When the face is held tightly against the opening the initiation of any sound, even a whisper, affects the tambour through the intervening column of air. However, it has the objection that, for fairly long times, the subject can not maintain his position, since breathing is necessarily stopped. Consequently, in long times, the subject must allow space between the face and the instrument for breathing. When the response is thought of, movement towards the instrument must be made. It is questionable, then, whether the difficulty has been wholly obviated.

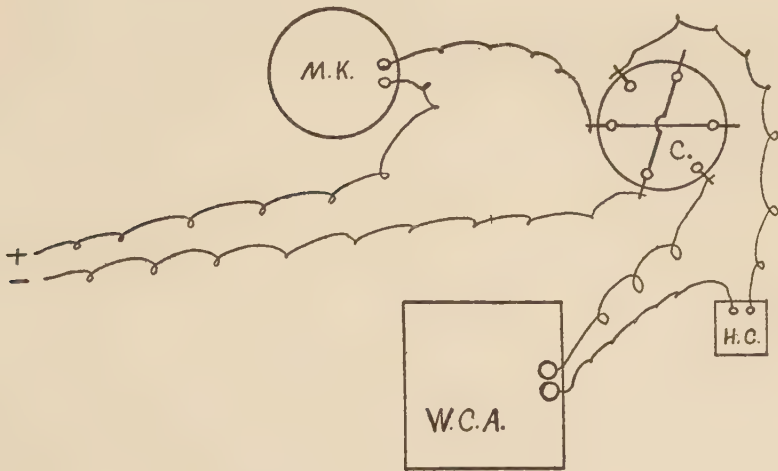


FIG. 1

D. NONSENSE SYLLABLES—THEIR PREPARATION

In the preparation of the nonsense syllables, the five vowels, a, e, i, o, and u, and all the consonants, were used. A nonsense syllable was composed of three letters, a vowel between two consonants. All syllables possible with the various combinations of vowels and consonants were made. Any syllable making a sense word was at once rejected. Syllables with the initial and final consonant the same were rejected. The remaining syllables—about 1400 in number—were written on slips of paper, placed in a bag, and thoroughly shuffled. They were then drawn by lot. Fourteen syllables were arranged in pairs, composing seven measures of two syllables each, with the following restrictions in mind:

1. The initial consonant, the vowel, and the final consonant of the first syllable should be different from the corresponding letters of the second syllable of the same measure.
2. The final consonant of the first syllable of a measure should be different from the initial consonant of the second syllable of the same measure.
3. Two syllables having an apparent sense association were not used to form a measure.

4. In the seven syllables, occupying the first-syllable position of the seven measures, all the vowels were represented, and two vowels were represented twice. The same applies to the seven syllables occupying the second-syllable position. The two vowels represented twice in the first position were not the same as those represented twice in the second position.

5. The initial letters of the seven syllables occupying the second-syllable position in the seven measures were all different. In the case of those occupying the first position, not more than two were alike.

6. The seven measures were arranged for learning so that successive vowels of the different syllables were not the same, and initial consonants of successive syllables were different. The end consonant of one syllable was different from the initial consonant of the succeeding one.

7. In a set of fourteen syllables, two syllables, with two letters of one syllable the same as the corresponding letters of the other, were not permitted.

The two syllables forming a measure were type-written upon slips of paper to fit the grooves of the exposure apparatus. The initial letter of each syllable was a capital, the other two being small pica letters. The spacing between two syllables of a measure was 2 cm.

In any experiment, when the stock of syllables was exhausted, new syllables were formed by dividing the total number of measures into three parts, the measures the subject first learned being used as the first part for forming new syllables. These measures were mixed thoroughly and drawn by lot, and new measures of syllables formed with the above seven restrictions in mind, and with the further restriction that two syllables, once forming a measure, were not used again for a measure. Usually the syllable occupying the first (second) half of a measure was used for the second (first) half of a new measure.

In a few instances errors of construction crept in but may be considered as negligible. It may be remarked that absolute equality of different series of syllables appears almost impossible.

Considering the matter of associations alone, a series of syllables, to the operator apparently free from associations, often occasions familiar associations to the subject. These can scarcely be avoided, since the associations of two individuals are often quite different, thus making it impossible for one to arrange wholly unassociated material for the other.

E. GENERAL METHOD

The general method of our Experiments I to XII may be briefly outlined. The subject, seated in front of the apparatus, is shown a series of fourteen syllables, seven measures, two syllables to the measure. The cylinder bearing the syllables is revolved by the operator at a uniform rate throughout the exposing process. The cylinder contains fourteen grooves for measures. Only alternate grooves are filled with measures. Each empty groove is exposed the same time as a filled one. Thereby the subject sees a pair of syllables for a certain time and, following this exposure, there is a rest interval of the same length. The subject repeats the syllables aloud as they pass. Equal times of exposure are obtained by the use of the metronome. Following the learning is an interval which may or may not, according to the day's position in the experiment, contain a sub-interval of mental activity. When this sub-interval was employed in mental activity, the signal used for the subject to begin was, "Work," spoken by the operator at the desired time. When the operator desired the subject to cease working, this was indicated by simply saying, "Rest." How much mental activity had to be engaged in, following the learning, was kept from the subject as nearly as possible. At the end of the interval, varying in length according to the experiment, came the test. While the subject was working or resting, as the case might be, the operator re-arranged the measures on the cylinder in an order different from that used in learning them. In the first test of each day the order of test of the measures, as compared with the exposure of them, was 5, 7, 1, 3, 6, 2, 4. In the second test of the day the order was 6, 2, 4, 7, 1, 3, 5. Only the first syllable of each measure

was shown for test. The method of test has been given under Apparatus. The operator notes the reply of the subject to each syllable shown, records the time, and adjusts the apparatus. The subject, each time after he has replied, makes the contact at the mouth-key for the next test. After the seven syllables are tested there follows a rest period, during which the operator records the introspections of the subject, and arranges a new set of syllables on the cylinder for the second learning, which follows after a rest period of not less than five minutes. Usually two series are learned and tested on any experiment day. The experiments on different days were made at as nearly the same hour of the day as possible.

In recording the responses of the subject to the various test syllables, it is to be noted that the first response—the one giving the time—is always used. A second response, though correct, is recorded but never considered as a correct response to the test syllable. The time given the subject to think of a suitable response is necessarily restricted to the limit of the chronoscope, which runs approximately one minute. It may be noted in advance that such long times are exceedingly rare.

The seven subjects¹ serving in the major portion of this work were:

Prof. W. B. Pillsbury,	(P.)
Dr. H. F. Adams,	(A.)
and Graduate Students,	
Miss Z. P. Buck,	(Z. B.)
Mr. W. H. Batson,	(B.)
Mr. F. C. Dockeray,	(D.)
Mr. H. V. Foulk,	(F.)
Mr. C. P. Wang,	(W.)

¹ To some of these the writer is particularly indebted in that he was unable to reciprocate their service.

F. EXPERIMENTAL SECTION

EXPERIMENT I

This experiment extended over a period of thirty-two experiment days. Successive experiment days do not necessarily coincide with successive calendar days, though for the most part they do. On each experiment day two series of seven measures each, two nonsense syllables to the measure, were shown to the subject. Sixteen repetitions were given for the learning. The rate of the revolving cylinder was kept constant by the use of a metronome. The metronome was set at seventy-two beats a minute. On each second beat of the metronome the operator allowed the cylinder, bearing the syllables, to move around one point. Thus a measure was exposed to the view of the subject one and two-thirds seconds, then a blank space was exposed for one and two-thirds seconds, then another measure for one and two-thirds seconds, and so on, until the requisite number of repetitions was given. This process is designated the *learning*. Following the learning there elapsed a period of time which we shall designate throughout as the *variant interval*. In the present experiment this interval lasted fifteen minutes. The mental activity of the subject during this interval is the important variable in our experiment. In this consists our variable factor, it being our purpose to keep, from day to day, all other factors as nearly constant as possible. The plan relative to the disposition of this interval for the different days may be given as follows:

Exp. Day	Series A		Series B	
	Rest	Work	Rest	Work
1	15	0	0	15
2	14	1	1	14
3	13	2	2	13
4	12	3	3	12
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
16	0	15	15	0
17	0	15	15	0
18	1	14	14	1
19	2	13	13	2
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
32	15	0	0	15

The caption "Series A" is used to designate the first series learned on any particular day. "Series B" refers to the second series of the same day. The total, as given above, we arbitrarily call a *cycle* of experiment days. Four results are obtained for any definite position in the variant interval, *e.g.*, take rest four and work twelve; this combination occurs four times in the cycle. It will be noted that this cyclic arrangement presents the following advantages:

1. The effect of any practice is fairly equally distributed. Thus it will be seen that the number of days' practice preceding any position in the variant interval is 31. *E.g.*, suppose we take rest 12, work 3. The days preceding the first result are three, those preceding the last result are twenty-eight.

2. The effect of fatigue is balanced. Any criticism that the B series had the disadvantage, because of the learning and test of the preceding A series, is evaded, at least as far as the comparative value of the results is concerned. In a complete cycle any position in the variant interval has occurred twice in the A and twice in the B series.

During that part of the variant interval not taken up with work, the subject sat quietly, having been instructed not to engage in any particular mental activity, but to rest as completely as possible. The work used in this experiment during the variant interval was cross-multiplication, the multiplicand and the multiplier each consisting of three figures. The process may be best given by an example. Take 736×284 ; the process is as follows:

$$\begin{array}{rcl}
 4 \times 6 & & = 24 \\
 4 \times 3 + 8 \times 6 + 2 & & = 62 \\
 4 \times 7 + 2 \times 6 + 8 \times 3 + 6 & & = 70 \\
 8 \times 7 + 3 \times 2 + 7 & & = 69 \\
 2 \times 7 + 6 & & = 20
 \end{array}$$

Hence the answer is 209024.

The subject is required to work all these steps mentally, *i.e.*, without recourse to notes, jotting down the figures "to carry," or similar aids.

The test follows immediately upon the variant interval. Between the closing of the test of the A series and the beginning

of the learning of the B series, there occurs, as noted before, an interval of at least five minutes, during which introspections and remarks of the subject are recorded. During this interval the subject is allowed to talk freely with the operator, walk about the room, etc., but is forbidden to do any thing that will act as an unusual excitant.

The subject used in this experiment was B. He was experienced in learning nonsense syllables, having acted as a subject in the preliminary experiments leading up to this work. He was exceptionally good at remembering nonsense syllables, if allowed to form sense associations between them when learning. This was noted in the preliminary experiments, and he was instructed not to form such associations. We may say that, at the beginning of the present experiment, his habit of forming such sense associations was fairly well broken.

The results of this experiment may be seen from the following curves, Fig. 2.

A and B are success curves. C is the time curve corresponding

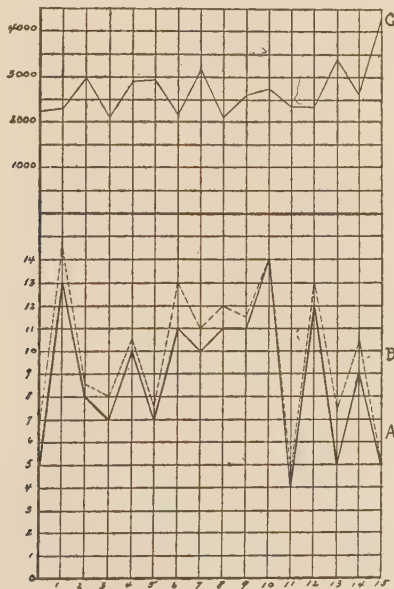


FIG. 2

to curve A. In all three curves the abscissae represent the number of minutes of the variant interval employed in mental activity. As the abscissae increase the work gradually fills the variant interval from the end backwards. *E.g.*, under abscissa 6 the experiments would be disposed; learning, rest nine minutes, work six minutes, and test. In curve A the ordinates represent the number of wholly correct responses obtained for the different abscissae. In B the ordinates represent the wholly correct responses plus the partially correct responses (two letters correct being the only ones considered), each of these latter evaluated at one-half—and not two-thirds—of a wholly correct response. In curve C the ordinates represent the average time, in sigmata, of the wholly correct responses corresponding to the different abscissae.

There were a few correct responses for which the operator, through his fault or some defect in the apparatus, failed to get accurate time. Consequently, in the computation of the time curve of the present experiment, as well as of those of subsequent experiments, any ordinate represents the average time for the wholly correct responses for which time was received.

The greatest number of successes was obtained with rest 5, work 10; the least number with rest 4, work 11—two adjacent points. Their separation along the Y axis, is greater than that between any other two points of the curve. One is hardly convinced of the validity of such a disparity existing between adjacent points. No essential difference between such points would be expected. To be sure, we should not attempt to draw too much from this experiment, because of the small number of results for each position in the variant interval. If we consider the success curve as a whole, we note that the general trend is slightly upward to point 10, from point 10 the general trend is slightly downward.

Curve B shows no particular value over curve A. Even with so few results, the nature of the two curves is not essentially different. With increasing numbers for the different ordinates, it appears that the character of the two curves would be less different. Consequently, it scarcely seems necessary, at least

for our main purpose, to consider the partial responses in the computation of the success curve.

If we consider the time curve, we note, starting with point 10, a general tendency upwards. Other than this the time curve shows no particularly clear relation to the success curve.

No elaborate introspections were taken in this experiment. It may be well to state that the subject repeatedly indicated that the influence of the interpolated work was not noticed, asserting, that if he had a syllable, he had it, and the work had no noticeable effect.

Relative to the maximum and minimum points of the success curve, it may be remarked that, under rest 4, work 11, one set of syllables, erroneously constructed, was given. The set yielded three correct responses. The other series of the day, with rest 11, work 4, yielded no correct responses. It would seem that if the erroneous construction—disobedience of restriction No. 5—had any influence, it favored the correct responses. If we allow for this, it would mean still greater disparity between abscissae 10 and 11, in that abscissa 11 would be still lower. On another day, with similar experimental conditions, save that the order of the variant interval was, in the A series, rest 11, work 4, and in the B series, rest 4, work 11; the former gave three correct responses, while the latter yielded none. The subject reported that he thought the result, in the latter case, was due, not to the work introduced, but to the difficulty of the series of syllables. If we consider it valid to allow for this, the height of abscissa 11 would be raised. We may balance this allowance against the previous tendency.

We present below a table giving in outline the setting and results of the different experiment days that are included under Experiment I.

TABLE I

E.D.	R.	W.	A. Series			B. Series			R.	W.
			S ₃	S ₂	S ₁	S ₃	S ₂	S ₁		
1	15	0	1	2					0	15
2	14	1	2	1	1	3	1		1	14
3	13	2					2		2	13
4	12	3	1	2	2	3		1	3	12
5	11	5	3	1				1	4	11
6	10	5	2		2	1			5	10
7	9	6	2	1		3			6	9
8	8	7			1	2			7	8
9	7	8	4			4	1	1	8	7
10	6	9	1	1		1	1		9	6
11	5	10	3			1		1	10	5
12	4	11	3	1	1				11	4
13	3	12	2	1		1			12	3
14	2	13				4	1		13	2
15	1	14	1	1		1			14	1
16	0	15	1			2			15	0
17	0	15	3			1		1	15	0
18	1	14	2	1		3	2		14	1
19	2	13	1	1		2			13	2
20	3	12	4			2			12	3
21	4	11	1		1	4		1	11	4
22	5	10	3			3	1		10	5
23	6	10	2			6	1		10	6
24	7	8	2	1		3	1		8	7
25	8	7	3			3	1		7	8
26	9	6	2	1		5			6	9
27	10	5	1			7			5	10
28	11	4	3					1	4	11
29	12	3	3		1	3	1		3	12
30	13	2	2		1	4	2	1	2	13
31	14	1	7			3			1	14
32	15	0	1	2		1			0	15
Totals			66	17	10	76	15	8		

Under E. D. we have the temporal order of any particular experiment day. R. and W. refer to the composition of the variant interval, following the A or B series, as the case may be. Under R. we have the number of minutes rest immediately following the learning of the A (or B) series before any work is engaged in. The number of minutes work employed is found under W. In the columns S₃, S₂, S₁, appears the absolute number of correct, partially correct (two letters of a syllable), and partially correct (one letter of a syllable), responses respectively. R. plus W. should, in every case, equal fifteen minutes, since fifteen minutes was taken for the length of the variant interval in the experiment. However, there are three instances in which this was not the case. In neither case does the additional minute

change the setting until after nine minutes after the learning of the syllables. The writer considers the point negligible. But, even if not so, the results of the particular day involved weight against (to anticipate) the general conclusion of this paper.

By referring to the table, we may compare the total successes of the A series with the total successes of the B series. We find for the A series, $\Sigma S_3 = 66$, $\Sigma S_2 = 17$, $\Sigma S_1 = 10$; for the B series, $\Sigma S_3 = 76$, $\Sigma S_2 = 15$, $\Sigma S_1 = 8$. The advantage in favor of the B series is a trifle greater than we should expect chance to give either series. Due to the mental activity connected with the A series, we may assume a slightly fatigued condition of the subject at the beginning of the learning of the B series. Hence, we should have expected the A, instead of the B, series to possess any slight advantage.

Of the thirty-two partially correct responses (two letters correct), twenty-two were of the Di- type, *i.e.*, the initial consonant and the vowel correct; seven were of the -it type, *i.e.*, the vowel and final consonant correct; while only three were of the D-t type, the initial and final consonants correct. This was to be expected since chance, in a combination of two letters, one of which is a vowel, favors a consonant and a vowel rather than two consonants. Further, we may explain the advantage of the Di- type over the -it type in accordance with the laws of association. Clearly, when the measure Loc Dit is learned, the association between Loc and Di is much stronger than that between Loc and it.

Of the eighteen cases of partial responses (one letter correct), ten of these letters were vowels, and eight were consonants. Of the eight consonants, four were initial and four were final. Here again we should expect the vowels, relatively, to have the advantage, since the number of vowels to select from is only one-fourth (approximately) as large as that of the consonants. The smallness of the number of each probably renders the results more or less meaningless.

A distribution of the total number of correct responses received, according to the position which they occupied in the learning, shows the following:

Position	No. of Successes
1	19
2	20
3	18
4	18
5	20
6	21
7	26

A further discussion of the point here involved will be deferred until later.

EXPERIMENT II

The subject for this experiment was F. The experiment continued sixty-four experiment days. Fourteen-syllable series were used. The velocity of exposure of the syllables was twenty-three and one-third seconds. The variant interval was fifteen minutes. The work used, cross-multiplication. In fact, the experiment is exactly similar to Experiment I, with two exceptions, (1) the present experiment was continued longer—to sixty-four days, instead of thirty-two; and (2) a different subject was used. Two complete cycles of results were obtained, giving eight results for each position in the variant interval. As nearly as possible, the same hour of the day on different experiment days was used. A curve plotted from the results of the experiment follows in Figure 3.

In curve A the abscissae represent the number of minutes worked for the different positions in the variant interval. The ordinates represent the total number of successes for any position. In curve B the abscissae are the same as in curve A. The ordinates, however, represent the values of curve A plus the partial successes. Only those responses with two letters correct, of the three of a syllable, are considered, and each one of these is valued at one-half the value of a successful response. The time curve is shown by curve C. Abscissae as in A and B. The ordinates represent the average time of the correct responses for any position in the variant interval.

The following points may be noted:

1. The lowest point of the success curve occurs with rest 1, work 14. The highest point occurs with the position rest



FIG. 3

2, work 13. These two points are adjacent, and it is hard to account for such a difference existing between two points whose position would seem, naturally, to merit no such distinction. We noted a similar occurrence in Experiment I, only in that experiment the divergent points were 11 and 12 instead of, as in the present experiment, 13 and 14.

2. To the lowest point of the success curve corresponds the lowest point of the time curve, but to the two next lowest points of the success curve correspond the two highest points of the time curve—two results that do not seemingly harmonize with themselves, and with what we might have expected. It would seem reasonable to suppose, from our general idea of retroactive inhibition, that with a large number of successes would correspond short times. But this is not the case in our curves. In fact, there seems to be no simple expressible relation between the

two curves. According to the results of Müller and Pilzecker this relation is an inverse one.

3. The undulatory character of the success curve, noticeable also in the success curve of Experiment I, is no less surprising than bewildering.

The writer wishes to call attention to the fact that the subject used in this experiment had had considerable experience in learning nonsense syllables previous to this experiment. Again, he did not have such a tendency to form sense associations as was the case with the subject in Experiment I. It may be well to mention here that subject F. and subject B. were quite different in temperament; subject F. being calm, deliberate, slow and easy going; while subject B. was quite the opposite, quick, active and alert.

Here, as in Experiment I, a large number of introspections is wanting. The subject reported no noticeable effect of the interpolated work. He reported that he though the process of multiplication tended to become a mechanical one, not requiring the closest attention. He had at one time held a clerical position requiring the constant use of figures. His idea was that such work may become automatic, columns of figures may be added while the attention is directed elsewhere. The writer has acted as subject where cross multiplication was used; he is also accustomed to the frequent use of figures in clerical work. With him the process in the cases cited seems to be far removed from the mechanical. To be sure, after a little practice, the work can be done with greater rapidity; the figures seem to fall into line, as it were; the result seems to come forthwith, but most successfully, only when the attention is closely given to the work in hand.¹

A table follows showing the setting and results of each day's experiment:

¹ Cf. Ladd and Woodworth's position relative to habitual actions, *Elements of Physiological Psychology*, 1911, p. 564.

TABLE II—A Series

E.D.	D--	Di-	-i-	-it	- -t	D-t	R.	W.	S ₃	S ₂	S ₁
1		I					15	0	3	I	
2		I	I				14	I	5	I	I
3			I		I		13	2	3		2
4		I	I				12	3	5	I	I
5		2			I	I	11	4	I	3	I
6		I		I			10	5	2	2	
7		I	I				9	6	3	I	I
8		I	I				8	7	3	I	I
9		I					7	8	3	I	
10		I					6	9	4	I	
11			I				5	10	2		I
12			I	I			4	11	2	I	I
13		3				I	3	12	3	4	
14		I					2	13	5	I	
15						I	I	14		I	
16							0	15	4		
17		I		I			0	15	5	2	
18		I		I			I	14	3	2	I
19				I			2	13	5	I	
20		I		I			3	12	5	2	
21				I			4	11	4	I	
22			I	I			5	10	2	I	I
23		2	I		I		6	9	I	2	2
24		I					7	8	6	I	
25			I	I			8	7	3	I	I
26			I				9	6	4		I
27				I			10	5	5	I	
28					I		11	4	5		I
29							12	3	7		
30							13	2	5		
31		I	I				14	I	4	I	I
32			I			I	15	0	4	I	I
33	I		I				0	15	4		2
34		I					14	I	6	I	
35		2	I				13	2	4	2	I
36			2	I			11	4	4	I	2
37		2					12	3	5	2	
38	I						10	5	4		I
39				I	I		9	6	4	I	I
40				I		I	8	7	2	2	
41							7	8	4		
42							6	9	6		
43		I	2				5	10	I	I	2
44			I		I		4	11	2		2
45				I			3	12	4	I	
46	I					I	2	13	4	I	I
47			I				I	14			I
48				I			0	15	5	I	
49			2	I			15	0	3	I	2
50		I					I	14	5	I	
51		I					2	13	6	I	
52		I					3	12	5	I	
53						I	4	11	4	I	
54			I				5	10	4		I
55							6	9	5		
56		I	2				7	8	I	I	2
57		2	I	I			8	7	I	3	I
58		I					9	6	6	I	
59		I		I			10	5	3	2	
60		2					11	4	3	2	
61				I			12	3	4	I	
62				I		I	13	2	4	2	
63		I	I				14	I	4	I	I
64							15		6		
	3	38	28	20	6	8			239	66	38

TABLE II--B Series

E.D.	S ₈	S ₂	S ₁	R.	W.	D--	Di-	-i-	-it	--t	D-t
1	2	2	1	0	15		1		1	1	
2	3			1	14						
3	4	1	1	2	13		1	1			
4	1	5	1	3	12		2	1	3		
5	2	1	2	4	11		1	2			
6	1	1	2	5	10	1		1	1		
7	3	2		6	9		2				
8	2	1	1	9	6	1	1				
9			3	8	7			1		2	
10	1	1	1	7	8		1	1			
11	3	2		10	5		2				
12	2	1	1	11	4	1	1				
13	2	1		12	3		1				
14	1		3	13	2			3			
15	1	2		14	1		2				
16	3	1		15	0		1				
17	1		5	15	0	2		3			
18	3	1	1	14	1		1	1			
19	4	2	1	13	2			1	2		
20	7			12	3						
21	1	1	2	11	4		1	1		1	
22	1	2		10	5		2				
23	3	1	1	9	6		1	1			
24	6	1		8	7		1				
25	3	2		7	8						
26	6			6	9						1
27	6			5	10						
28	3	2		4	11		2				
29	5	1		3	12		1				
30	5		1	2	13			1			
31	1	2	2	1	14		1			2	1
32	4		2	0	15			2			
33	5		2	15	0			2			
34	3	1	1	1	14		1	1			
35	7		2	2	13						
36	2	1	3	4	11	2	1	1			
37	5			3	12						
38	1	1	3	5	10			3	1		
39	4			6	9						
40		2	4	7	8			4	2		
41	4		1	8	7			1			
42	4		1	9	6					1	
43	4	1		10	5				1		
44	5		1	11	4			1			
45	2		1	12	3	1					
46	5	1		13	2						1
47	4	1		14	1				1		
48	3	1		15	0		1				
49	3	3	1	0	15		1	1	2		
50	2	2	1	14	1	1	1		1		
51	7			13	2						
52	4	1	1	12	3	1	1				
53	4	1	1	11	4		1	1			
54	5	1	1	10	5			1	1		
55	6			9	6						
56	3	2	1	8	7		2	1			
57	4		3	7	8			2			
58	4	2		6	9		2			1	
59	4			5	10						
60	2	2		4	11		1				1
61	4		1	3	12			1			
62	3		1	2	13	1					
63	3		3	1	14			3			
64	4	2		0	15		2				
	210	61	62			11	40	43	17	8	4

The significance of the different abbreviations is fully explained under Table I, Experiment I, page 20.

A point, scarcely worthy of note, is that the temporal order of the experiments on the eighth, ninth, and tenth days, is the reverse of our plan. The same occurs with days 36 and 37. The A and B series of days 33 and 49 are the reverse of the planned order. Both days, however, correspond in setting, hence the reversal of one practically equalizes the reversal of the other.

In our present results, of the total successes for the A and B series, we note quite the opposite to that received in Experiment I. The A series gives, on the whole, $\Sigma S_3=239$, $\Sigma S_2=66$, $\Sigma S_1=38$; while the B series gives $\Sigma S_3=210$, $\Sigma S_2=61$, $\Sigma S_1=62$. We may explain our present result in accordance with our previous reasoning, (p. 21), that the second set of the day may be at a slight disadvantage. This, together with chance variation, we may say, gives rise to the difference existing between ΣS_3 of A and ΣS_3 of B.

We wish to mention another point, the details of which are not presented. If we proportion the total 449 (ΣS_3 (A) plus ΣS_3 (B)) correct responses according to their temporal order, as respects measures, in the learning, we obtain:

Position	Responses
1	74
2	51
3	60
4	62
5	66
6	63
7	72

It was very noticeable with subject F. that he often knew the position a syllable occupied in the learning when he could not recall that syllable. It is to be remembered that the order of the syllables in the test was not the same as that in the learning, and the order for the test of the A series was not the same as that for the B series.

The subject remarked that the syllable learned first often fails to come up in the recall. We could attribute this to an assurance at the first causing a comparative lack of attention to that syllable in the latter part of the learning process. The subject also noted

that he thought the getting of the response to the first test syllable had a particular influence upon the total successes of that trial. His idea being, *caeteris paribus*, a successful response to the first test syllable initiates a kind of systematic preparation for the responses to the remaining test syllables. Theoretically, this appears plausible; if we assume the subject has a certain stock of correct responses, consciously or unconsciously, at the beginning of the test, the precipitation of any one of them may prepare the remaining and lend a certain amount of impetus, due to the feeling tone connected with the successful response. This effect, coming at the beginning, is much more potent, since the succeeding test syllables are unimpaired by any unsuccessful inhibiting attitude, which is necessarily the case when the first or first and second responses are unsuccessful.

The subject's idea of how he gets the correct responses may be instructive. They are due to one, or some combination of, the three factors, (1) direct association, (2) getting the position occupied by the syllable in the learning, and (3) running over the stock of syllables on hand. Towards the end of the experiment the subject indicated that there was much more to learning a set of syllables than the mere allowing them to pass before the field of vision, framing his view, "Some force is let loose that feels like an original will-power"; meaning probably nothing more than a concentration of attention, or, as expressed by Ladd and Woodworth² "setting up a favorable adjustment."

EXPERIMENT III

The two previous experiments have partially indicated the difficulty of our task. It is to be remembered that the present work was intended to be an elaboration of the work done by Müller and Pilzecker on retroactive inhibition. Consequently, we assumed their work as a base. Neither our preliminary experiments nor the two experiments given above, showed any evidence that we were going to receive any such "striking" results as those received by the German investigators. Naturally, it appeared necessary to conduct experiments, similar to the ones

² *Elements of Physiological Psychology*, 1911, p. 582.

carried out by them, for the purpose of confirming their results, or establishing new ones.

The general method of this experiment was similar to that of Experiments I and II, but different from them in that, in our present experiment, only two points of the variant interval are under investigation. On each experiment day two series—an A and a B—of seven measures, two syllables to the measure, were learned. Ten repetitions were used for each series. Subject B., the same as in Experiment I. Following the learning of one series, there was a rest period of fifteen minutes, then the test. Immediately following the learning of the other series, the subject engaged in cross multiplication for ten minutes. A rest period of five minutes followed the multiplication, then the test was made. On one day the multiplication was placed in the A series, on the next day it was placed in the B series. This gives us an equal distribution between the A and B series of the deleterious effect of any fatigue, arising from having learned a previous set of syllables. Of course, even then, the objection lies open that, from the standpoint of fatigue, the set with work following has a slight advantage in that, when it occupies the second position (B series), no work was done during the preceding variant interval. When the set, with no work following, occupied the second position, ten minutes of work were engaged in during the variant interval of the first set.

The experiment extended over a period of 16 experiment days with the following results, $n = 112$:

TABLE III

		S_3	r	m.v.	%	S_2	S_1	T_r	$T < 2000\sigma$	$T < 1500\sigma$
Cs. I.	Rest 15	54	3.4	1.6	48	5	4	2221	31	22
Cs. II.	Work 10, Rest 5	37	2.3	1.0	33	4	4	2673	15	9

The above table gives the absolute number of successes, S_3 ; the average number in a set, r ; the per centum, %; the mean variation, m.v.; the number of syllables, two letters correct, S_2 ; the number of syllables, one letter correct, S_1 ; the average time for the correct responses, T_r ; the absolute number of correct responses with time less than 2000 sigmata, $T < 2000\sigma$; and the number with time less than 1,500 sigmata, $T < 1500\sigma$.

The results obtained in this experiment seem to favor the assumption that retroactive inhibition plays a part under such conditions as those of Case II. However, the force of these results becomes somewhat weakened, when viewed in connection with those received in the next experiment with the same subject.

EXPERIMENT IV

The present experiment extended over a period of ten experiment days. Subject, B. Seven-measure nonsense syllables were repeated ten times. The variant interval of fifteen minutes was thus disposed. On each experiment day two series were learned. Immediately following one series there elapsed a rest period of six minutes, the remaining nine minutes were occupied in cross-multiplication. Following the other set there elapsed a rest period of two minutes, then thirteen minutes of cross-multiplication. At the close of the variant interval, the syllables were tested. A rest period of at least five minutes occurred between the test of the first and the learning of the second series on any experiment day. On one experiment day the variant interval, containing the rest six minutes, work nine minutes, followed the learning of the A series; on the next day it followed the learning of the B series. The results follow in Table IV, $n = 70$:

TABLE IV

		S_2	r	m.v.	%	S_2	S_1	T_r	$T < 2000\sigma$
Cs. I.	Rest 6, Work 9....	20	2	1	29	3	2	2675	14
Cs. II.	Rest 2, Work 13....	26	2.6	1.6	37	2	0	3328	11

Above is given, in tabular form, the absolute number of successes, S_2 ; the average number, r ; the mean variation, m. v.; the per centum, %; the number of syllables, two letters correct, S_2 ; the number of syllables, one letter correct, S_1 ; the average time for the correct responses, T_r ; and the absolute number of correct responses with time less than 2000 sigmata, $T < 2000\sigma$.

Attention may be called to the fact that Case II, though its variant interval contains more work, and given sooner after learning, than Case I, gives more successful responses. The

average time for Case II is longer than that for Case I. There appears no evident reason for the getting of more successes in Case II. The suggestion offers itself that the greater mental activity of Case II placed the subject in a condition of better mental preparedness for the test than did Case I. Assuming the activity of retroactive inhibition, the time result is what we should expect.

The results of this experiment suggest that two minutes after the learning of a series, retroactive inhibition plays no noticeable part in diminishing the number of successful responses, though it may appear in a slight retardation of the correct responses. The author realizes that the meagreness of numbers, if we consider in isolation the experiment at hand, is a serious drawback to final acceptance of any apparent conclusions therefrom.

EXPERIMENT V

This experiment was conducted exactly as Experiment IV, save with a different subject, subject D., and with an essential change with respect to the variant interval. In the present experiment, the variant interval of fifteen minutes was thus occupied; the subject either cross-multiplied the full time, beginning immediately after learning, or he rested the full time. On one day the cross-multiplication came after the A series, on the next day it came after the B series. The subject was an experienced one in learning nonsense syllables. He tended rather toward the steady, slow, deliberate temperament. The experiment continued for ten experiment days, with the following results; Table V, $n = 70$:

		TABLE V							
		S_8	r	m.v.	%	S_2	S_1	T_r	$T < 2000\sigma$
Cs. I.	Rest 15.....	24	2.4	.96	34	4	9	5149	6
Cs. II.	Work 15.....	21	2.1	1.31	30	5	5	5822	2

The column symbols have exactly the same meaning as those used in Experiments III and IV, p. 29f.

Case I shows a slight advantage over Case II, with respect to the number of successful responses. A *slight* advantage is

all that can be claimed; even that—it is not unreasonable to assume—may have been due to mere chance. To be sure, the argument works both ways equally well; it may be claimed that chance favored the results of Case II.

Surely, if we are to obtain a retroactive effect, it should have appeared in Case II, with fifteen minutes work immediately subsequent upon the learning. Shall we then tend towards some such conclusion as the non-existence of retroactive inhibition? Or, shall we refrain—doubtless the better way—on account of the paucity of results, from drawing any general conclusions, until the question is more fully investigated? It seems that we may be allowed to question the importance of the part retroactive inhibition has hitherto been assumed to play in influencing the recall of nonsense syllables.

EXPERIMENT VI

The plan of this experiment was the same as that pursued in the preceding experiment, save that in this a different subject, subject W., was used, one who had not had very much experience in learning nonsense syllables. Ten repetitions were given each set of seven-measure syllables. The variant intervals were of two kinds, one where the subject rested the full fifteen minutes; the other where immediately after the learning, the subject worked at cross-multiplication for ten minutes, and then rested the remaining five minutes. The test followed the variant interval. The experiment continued nine experiment days. The results obtained are given below in Table VI, $n = 63$:

TABLE VI*

	S_3	r	m.v.	%	S_2	S_1	T_r	$T < 2000\sigma$
Cs. I. Rest 15.....	50	5.6	1.2	79	5	0	2828	18
Cs. II. Work 10, Rest 5....	43	4.8	1.3	68	2	1	2955	12

The symbols at the head of the different columns have been fully explained. See above under Experiments III and IV, p. 29f.

We note here an advantage in favor of Case I, in respect both to the number of correct responses, and the celerity of the response. The advantage, however, is not a decided one; especially is this the case with respect to time. It is noticeable that Case I

shows more correct responses with reaction time less than 2000 sigmata. The advantage in favor of Case I, on the part of the successful responses, seems too large to be wholly accounted for on the basis of variation and chance.

EXPERIMENT VII

W. acted as subject for the present experiment. The only essential difference between the setting of this experiment and that of Experiment VI, lies in the fact, that, in the learning, the syllables were presented auditorially instead of visually. This was accomplished by reading the syllables to the subject. Six repetitions were given each series. The metronome was set at 72. The operator began a measure on one stroke of the metronome and ended on the next; two strokes were allowed for rest; then a new measure was read. For the test additional apparatus was used, a second mouth-key, a lamp battery and a relay. It will be recalled that the mouth-key is fitted with tambour and metal pointer for breaking a circuit only. With the use of two circuit breakers alone, the use of the chronoscope is impractical either with open or closed circuit. The difficulty is obviated by the use of the lamp battery and the relay apparatus. The set-up may be shown diagrammatically as follows, Fig. 4:

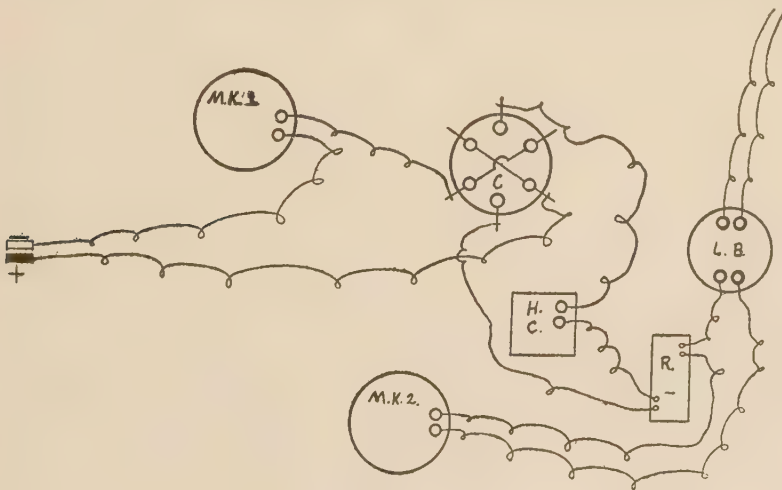


FIG. 4

M. K. 1, mouth-key for the subject; C., commutator; L. B., lamp battery; H. C., Hipp chronoscope; R., relay; and M. K. 2, mouth-key for the operator.

The complete apparatus was used only in the test. The purpose of the lamp battery and relay was to give a closed circuit through the chronoscope, when the operator spoke the test syllable into M. K. 2. The subject's response was spoken into M. K. 1. A rubber tube led out from M. K. 2 to the subject's ear. The subject's end of the tube was fitted with a common phonographic listening device. This device consists of a concavo-convex disk (diam. 5 cm.) of wood, through the centre of which runs a short piece of tin tubing.

The experiment continued ten experiment days with the following results, Table VII, $n = 70$:

		S_s	r	m.v.	%	S_2	S_1	Tr	$T < 2000\sigma$	$T < 3000$
Cs. I.	Rest 15	28	2.9	1.1	41	11	6	5127	7	11
Cs. II.	Work 10, Rest 5..	28	2.8	0.7	40	15	4	4286	4	11

The meaning of the headings of the different columns is fully explained under Experiments III and IV, p. 29f., save that we have added a column, $T < 3000\sigma$, which includes the absolute number of successes with time less than 3000 sigmata. It should be mentioned that the measure of correctness of a response consisted in its agreement with the correct syllable in sound, and not in spelling, as in the case of those syllables given visually.

We note here, with respect to the number of successful responses, practically no particular advantage shown by either case. An exceptional result occurs in that the average time for the correct responses of Case II is less than that for the correct responses of Case I. In our previous experiments, the average time for Case II has always been greater than that for Case I. Case I shows an advantage in the number of very short times, less than 2000 sigmata, seven as compared with four for Case I, but when 3000 sigmata is the maximum time for comparison, both cases yield the same number of times less than that amount.

EXPERIMENT VIII

The general method of this experiment was the same as that used in Experiment VI. D. acted as subject; fourteen-syllable nonsense series were used. Two sets were learned on each day. A variant interval of sixteen minutes was thus disposed: Instead of using cross-multiplication as interpolated work, as in the previous experiments, physical work was employed. The subject was harnessed to an ergograph, so that the weight would be lifted from the shoulders. The lifts were made with the metronome, one every two seconds. Immediately after the learning of one set of syllables, one minute was taken for adjustment of the apparatus to the subject, then came ten minutes work with the ergograph, followed by a rest of five minutes, then the test. In a second case no work followed the learning of a series of syllables. On one day the work came in the A series, on the next day it came in the B series. The experiment continued nine experiment days, giving the following results, Table VIII, $n = 63$:

TABLE VIII

		S_3	r	m.v.	%	S_2	S_1	T_r	$T < 2000\sigma$	$T < 3000\sigma$
Cs. I.	Rest 16.....	42	4.7	1.2	67	4	4	4862	13	19
Cs. II.	Adj. 1, Erg. 10, Rest 5....	27	3.0	0.9	43	2	2	4108	8	14

For explanation of symbols used see Experiments III, IV and VII.

Here we have quite an advantage in favor of Case I. The number of successes afforded by Case II is open to the very serious objection that its smallness may be due to physical fatigue rather than retroactive inhibition. The difference is quite explainable upon the basis that, at the time of the test, the lingering fatigue sensations, together with the associated complex of "sensations of rest," prevented complete attention to the recall of the learned nonsense syllables. This, it appears to the writer, is a sufficient explanation of the existing difference, without necessitating the employment of a shock effect of the physical work upon the learned syllables. In case the shock effect existed, the present experiment was not adequately designed to differentiate it from the fatigue effect.

EXPERIMENT IX (a)

Hitherto, in our discussion, we have been hampered and forced to refrain from any final conclusions because of the paucity of numbers. Hence it was desired to conduct an experiment to such length that the weight of numbers should not be wanting. It was the experimenter's purpose, in the present experiment, to meet such a requirement. In order that the work might not become too laborious, and extend to too great length, fewer points of the variant interval were taken for investigation than were taken in Experiments I and II, whose general plan the present experiment follows. The length of the variant interval was fifteen minutes. The first six minutes of the variant interval were the only ones subjected to variance, the other nine minutes serving as a rest period previous to the test. In justification of so narrowly restricting the variant part, we may cite experiments I to VII. From them the only conclusion relative to retroactive inhibition, we wish to urge, is that mental activity, following three or four minutes after the learning of a set of nonsense syllables, produces no apparent retroactive effect upon the number of successful responses in the recall. Consequently, we consider the limits of the variant factor in the present experiment as sufficient, and deem more extended limits unnecessary in the investigation of the factor under consideration.

Seven measures, two syllables to the measure, were repeated ten times by the subject. The first six minutes following the learning were disposed in accordance with the day's position in the cyclic order. In consequence of the length of the variant part of the variant interval, the cycle, which is fully explained *supra*, (p. 15f.), consists of fourteen experiment days. Following the variant interval of fifteen minutes came the test. Here the experiment days follow fairly closely the calendar days. In all instances the work is carried out in the afternoon, and for the most part at the same hour of the day.

Z. B. served as subject. The experiment continued seventy days, thus completing five cycles, and giving twenty different results for each point in the variant part of the variant interval. A success curve, A, and a time curve, B, plotted from the results, follow in Figure 5, $n = 140$:

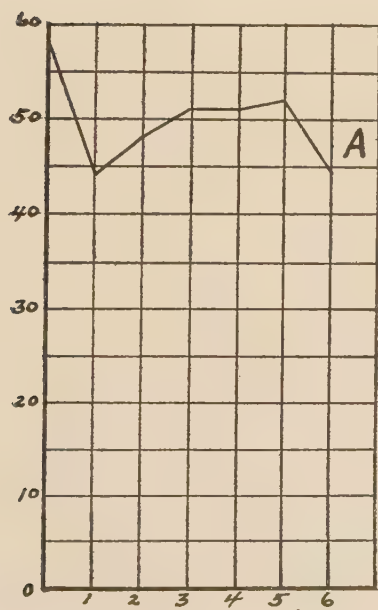
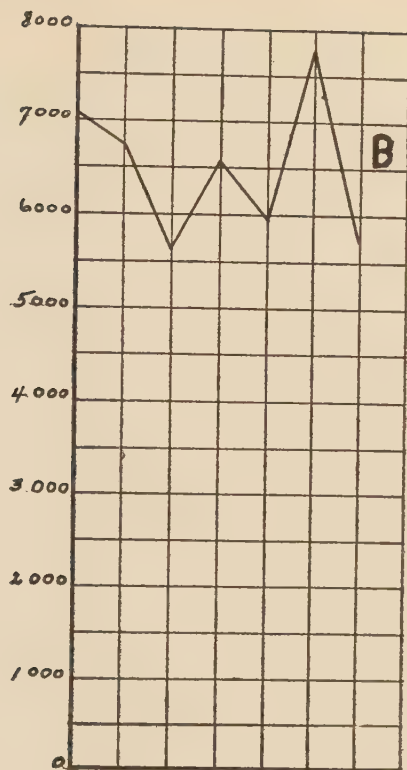


FIG. 5

A is a curve representing the total successes. B represents the time curve. In A and B the abscissae represent the number of minutes in which mental activity (cross-multiplication) was employed in the variant part of the variant interval; *e. g.*, abscissa 4 corresponds to the day's arrangement, learning, rest two minutes, work four minutes, rest nine minutes, and test. In A the ordinates represent the relative number of successful responses. In B the ordinates represent the average time of the successful responses.

A subsidiary curve, plotted in accordance with the method used in plotting Curve B, Fig. 2, p. 17f. and Curve B. Fig. 3, p. 22f., shows no essential difference from our present Curve A, the courses of the two curves always running in the same direction. Consequently this curve has been omitted.

The highest ordinate of the success curve occurs under abscissa 0, where no work occurred in the variant interval. A seemingly non-harmonizing result occurs in that abscissa 1 vies with abscissa 6 for the lowest point of the curve. In order to consider the results more in detail two tables, Table IX and Table X, are subjoined.

TABLE IX
Minutes Worked

0			1			2			3			4			5			6		
S ₃	S ₂	S ₁	S ₃	S ₂	S ₁	S ₃	S ₂	S ₁	S ₃	S ₂	S ₁	S ₃	S ₂	S ₁	S ₃	S ₂	S ₁	S ₃	S ₂	S ₁
4		I	3			3	I	I	4			I	I	I	4		I	3	I	I
6				I	I	2			I	2	3				4			3	I	
I	I	I	3			I	I		2		3	I	I	I	2		I	I	I	I
	2	2				3			I	I	3		I	I	I		I	I	I	
II	I	4	8	I	I	9	2	I	7	I	3	10	2	3	II	I	2	7	4	2
2	2	I	3			I		I	2	2			2			2	2	2	I	I
I		I	2		I	3		I	I	2	I	3		I	I	I	I	2	I	2
3				I	I	I	2		3		2	3			2	2	3	4		I
I		2	3			2		3	6	I			2	2	3	I				
18	3	8	16	2	3	16	4	6	19	6	6	16	6	6	17	5	7	18	6	6
4		2	2	I		I			2	I					I			I	I	
3	I		2		I	I			2	2	I	I		4	4	I		I	2	
				2	I	2	2		2	I	I	5			I		2	2	I	
3		2	4			2	I		4	I		4			I	2	I	4		
28	4	12	24	5	5	22	7	6	29	II	8	26	6	10	23	9	10	23	9	10
4	I		4		I	2	2		3		I	4		I	3			I		I
3			3		2	2			4			3			2		I	5		
3	I		3			4			I		I	5			6			3		
3	2		I			3		I	4	2		2	2		2	2		2	I	3
41	8	12	35	5	8	33	II	7	41	13	10	40	8	II	36	II	II	34	10	14
6		I	4		I	3			I	I	I	4			4	I	I	2		I
3			2			4		I	2		I	I			4		I	2		I
I		I				5			4		I	2			4		I	2		I
7			3			3	I	2	3	I	I	4			4		I	4	I	
58	8	14	44	5	9	48	12	10	51	15	14	51	8	II	52	12	15	44	II	17

The figures at the head of the different columns correspond to the different abscissae of the curves. Under S_3 appears the number of wholly correct responses; under S_2 , responses with only two letters correct; and under S_1 , responses with only one letter correct. The totals at the end of each cycle, give the total number of responses, under the different columns, up to that time, and not the totals of the immediate cycle under which they are placed. The writer's opinion is that more is to be gained from a consideration of this table than from a consideration of the Curve A.

We note that work 0, when compared with work 6, has the advantage all the way through, save in the second cycle, where the reverse is the case, giving at the end of the second cycle, where $n = 56$, the same number of successful responses to the credit of each. A point of great significance is that abscissa 0 did not gain its ascendancy over all other points until in the fifth cycle. At the end of the second and third cycles, abscissa 3 was in the ascendancy and maintained an equality at the end of the fourth cycle, losing out only in the fifth cycle. Abscissa 6 did not uniformly occupy the lowest position, in fact, never occupying the lowest position of all. At the end of the fourth cycle, $n = 112$, abscissae 6, 5, 2, and 1 were practically on an equal footing. These considerations seem to indicate that the ascendancy given to abscissa 0 at the end of the fifth cycle is not unquestionable. In fact, the results of the fifth cycle seem to play an unnatural part, as respects both abscissae 0 and 6. In the light of the results of the first four cycles, its value as a determinant of the final figures, seems too great. Hence, the curve from the results at the end of the fifth cycle can not be taken, without question, as a finality, representing the true status of the matter.

Again, if we consider the part of Curve A on each side of its mid-abscissa, i.e. 3, we get the total number of successes of the half towards abscissa 0, and that towards abscissa 6, equalling $175\frac{1}{2}$ and $172\frac{1}{2}$ respectively—their difference being wholly insignificant. This is an important fact, highly indicative, that the true path of the curve is along the horizontal, and consequently arguing against any effect of retroactive inhibition.

For a consideration of further details, we append the second table, Table X:

E.D.	TABLE X—A Series					R.	W.	S ₃	S ₂	S ₁
	D--	Di-	-i-	-it	- -t					
1			I			6	0	4		I
2			I			I	5	4		I
3	I	I				4	2	3	I	I
4						3	3	4		
5						4	2	2		
6		I			I	5	I		I	I
7						6	0	6		
8		I			I	0	6		I	I
9			I			I	5	2		I
10	I	I				2	4	3	I	I
11						3	3	2		
12			I			2	4	3		I
13						5	I	2		
14		I				0	6	I	I	
15		2			I	6	0	2	2	I
16						5	I	3		
17					I	4	2	I		I
18		I		I		3	3	2	2	
19					I	2	4	3		I
20		I			I	I	5	I	I	I
21					2	I	0	6	I	2
22	I					0	6	3		I
23			2			I	5	2		2
24						2	4	3		
25			2			3	3	3		2
26			I		2	4	2	2		3
27						5	I	3		
28			I		I	6	0	I		2
29			I		I	6	0	4		2
30				I		5	I	2	I	
31						4	2	I		
32						I	3	2	I	*
33	I		I		2	2	4	I		4
34		I				I	5	4	I	
35			2			0	6	I		2
36			I	I		I	0	6	2	I
37			2			I	5	I		2
38						2	4	5		
39		I	I			3	3	2	I	I
40			I		I	6	0	3		2
41				I		4	2	2	I	
42						5	I	4		
43		I				6	0	4	I	
44			I			5	I	4		I
45		2				4	2	2	2	
46			I			3	3	3		I
47						2	4	3		
48	I					I	5	2		I
49						0	6	5		
50						0	6	3		
51						I	5	6		
52						2	4	5		
53					I	3	3	I		I

TABLE X—A Series (continued)

E.D.	D--	Di-	-i-	-it	-t	D-t	R.	W.	S ₈	S ₂	S ₁
54			I				4	2	3		I
55							5	I	I		
56		I				I	6	0	3	2	
57			I				6	0	6		I
58	I						5	I	4		I
59							4	2	3		
60		I			I		4	2	I	I	I
61							2	4	I		
62					I		I	5	4		I
63			I				0	6	2		I
64			I				0	6	2		I
65			I				I	5	4		I
66							2	4	2		
67			I				3	3	4		I
68		I	2				4	2	3	I	2
69							5	I	3		
70							6	0	7		
	6	17	29	4	18	4			190 55%	25	53

TABLE X—B Series

E.D.	S ₈	S ₂	S ₁	R.	W.	D--	Di-	-i-	-it	-t	D-t
1	3	I	I	0	6	I			I		
2	3			5	I						
3	I	I	I	2	4			I	I		
4		I	2	3	3	I	I	I			
5	3			2	4						
6	4			I	5						
7	3	I		0	6		I				
8	I	I	I	6	0			I	I		
9	3			5	I						
10	I	I		4	2				I		
11	I		I	3	3			I			
12	3			4	2						
13	I	I		I	5		I				
14			2	6	0			2			
15	2	I	I	0	6		I	I			
16		2	2	I	5	I	2	I			
17		2		2	4		I				I
18	I	2	I	3	3		2	I			
19	3		I	4	2			I			
20	2		I	5	I			I			
21	I		I	6	0			I			
22	3			6	0						
23		I	I	5	I		I	I			
24	I	2		4	2		I		I		
25	6	I		3	3		I				
26		2	2	2	4	I	2	I			
27	3	I		I	5		I				
28	4			0	6						
29		I	I	0	6		I	I			
30		I		I	5		I				
31				2	4						
32	2	2	I	3	3		I	I	I		
33	I			4	2						
34	2		I	5	I			I			

TABLE X—B Series (continued)

E.D.	S ₃	S ₂	S ₁	R.	W.	D--	Di-	-i-	-it	--t	D-t
35	3	1		6	0		1				
36				6	0						
37		2	1	5	1		1	1			1
38	2	2		4	2		2				
39	4	1		3	3		1				
40	4			0	6						
41	4			2	4						
42	1	2	1	1	5		2	1			
43	1		1	0	6	1					
44	3			1	5						
45	4		1	2	4			1			
46	4			3	3						
47	2	2		4	2		1		1		
48	3		2	5	1	1		1			
49	3			6	0						
50	3	1		6	0				1		
51	3			5	1						
52	4			4	2						
53	4	2		3	3		1		1		
54	2	2		2	4		1		1		
55	2	2		1	5		2				
56	2	1	3	0	6	1		2	1		
57	2		1	0	6			1			
58	4	1	1	1	5			1	1		
59	4			2	4						
60	2		1	3	3			1			
61	4		1	4	2	1					
62	2			5	1						
63	3			6	0						
64	1		1	6	0			1			
65				5	1						
66	5			4	2						
67	3	1	1	3	3		1	1			
68	4			2	4						
69	4	1		0	6		1				
70	4		1	1	0	1					
158	46		37			9	32	28	12	0	2
45%											

The meaning of the symbols used has been given under Experiment II. A few partial displacements appear in the cyclic order, but, due to the brevity of the cycle, this appears negligible. Under E. D. 60, it will be noted that R. 4, W. 2 has been reckoned as R. 3, W. 3. This appears permissible, since, had the additional minute of work been engaged in, the result could hardly have fallen lower in that particular instant. Even as it was, the result is below that of the B series with the same point on the same day.

ΣS_3 of the A series equals 190, while ΣS_3 of the B series equals only 162, the percentages being 54.6 and 45.4 respec-

tively. In explanation of this difference, we may refer to our discussion under Experiment I. We note here, as previously, that the Di- type of partial successes far outstrips the -it type, the former giving, *in toto*, 49; and the latter, 16. The D-t type is fairly negligible, giving, in all, only six occurrences. In the one-letter-correct syllables, the vowels far exceed either the initial or the final consonant; in fact, the vowel occurs oftener than both combined.

If we take the total number of successes, *i.e.*, $\Sigma S_3(A)$ plus $\Sigma S_3(B) = 348$, and consider them relatively to the position they occupied in the learning, we get the following distribution according to measures:

Position	Responses
1	58
2	40
3	48
4	45
5	49
6	44
7	64

These results seem to indicate, as those in Experiment II, that syllables occupying the first and seventh measures, are more firmly associated in the learning process. Further, the seventh position seems to possess this advantage to the greatest extent. The results of Experiment I do not accord upon this latter point. In explanation, it may be suggested that the beginning and end syllables have special attention called to them, in that they begin and end the series. But since the repetitions are continuous, and there is no break at the end of the seventh position different from that at the end of any other position, except, of course, at the closing of the learning process, this attentive distinction seems a rather meagre explanation for the disparity at hand. A second explanation offers itself. Regardless of the continuity of the learning process, the subject is nevertheless aware, as the repetitions continue, of the end and beginning of the series. Hence, a characteristic difference qualifying positions 7 and 1. Without mentioning the results, the subject of the present experiment was questioned about the consciousness of such a distinction. The reply was in the negative. A

knowledge of the position in the series occupied by a syllable, with Z. B., seemed to be much less than that possessed by subject F., in Experiment II. The second explanation seems valid in case of the results with subject F., but appears somewhat lacking in explanation of the greater difference obtained with Z. B., unless we assume that the same attentive distinction was present, but subliminal. Even at that, we should hardly expect the difference to be greater in the latter case. Subject B. of Experiment I does not show the characteristic under discussion with respect to the first position. He does show it in case of the seventh position. No reason for the difference in case of subject B. is forthcoming, unless we ascribe it to the insufficiency of numbers.

The learning process (*Vorzeigen*), used by Müller and Pilzecker,¹ for the most part, gave between the last and the first syllable of a series, a longer interval than occurred between any other two adjacent syllables. Such a procedure, we may assume, slightly accentuates the importance of the last and first syllables. Their Experiment 28 was conducted with no such distinguishing difference qualifying the last and first syllables. The order of the positions occupied by the syllables in the learning, in accordance with the largeness of the number of syllables obtained, was 5, 4, 3, 6, 2, 1.

If we turn to a consideration of the time curve, we find, as in Experiments I and II, no apparent general relation between the time and the success curves. In four instances there is concordance of direction, in two instances there is opposition. If we except the fifth abscissa, the general trend of the curve is downward. It is to be noted, that with the two highest points of the success curve correspond the two highest points of the time curve, and with the lowest point of the success curve corresponds the lowest point of the time curve. These results militate against any general statement of the relation of the success and time curves as one of inverse variance. Our average time is somewhat longer than that obtained by Müller and

¹ *Loc. cit.*, S. 266.

Pilzecker. This appears partially explicable in that in the present experiment the average percentage of successful syllables was fairly low. The number of repetitions was restricted lest the subject should too often get all the response syllables correct. This would have a tendency to give comparatively long times. That the explanation is adequate for the full difference, can scarcely be affirmed or denied.

Constructing a table showing the average time under each abscissa at the end of each cycle we have Table XI.

TABLE XI

Work	0	1	2	3	4	5	6
Cycle 1....	7172 <i>6</i>	3393 <i>1</i>	3782 <i>2</i>	3816 <i>3</i>	5431 <i>5</i>	8460 <i>7</i>	3867 <i>4</i>
Cycle 2....	5216 <i>4</i>	4108 <i>1</i>	5998 <i>5</i>	4945 <i>3</i>	6594 <i>7</i>	6518 <i>6</i>	4629 <i>2</i>
Cycle 3....	5866 <i>5</i>	5502 <i>3</i>	5400 <i>2</i>	5633 <i>4</i>	6328 <i>6</i>	6518 <i>7</i>	4402 <i>1</i>
Cycle 4....	6451 <i>5</i>	6544 <i>6</i>	6381 <i>4</i>	5786 <i>3</i>	5570 <i>2</i>	6557 <i>7</i>	4740 <i>1</i>
Cycle 5....	7039 <i>6</i>	6756 <i>5</i>	5625 <i>1</i>	6548 <i>4</i>	5967 <i>3</i>	7773 <i>7</i>	5706 <i>2</i>

The italicized figures represent the order of the length of time of the particular abscissa in the particular group. It is noticeable that abscissa five maintained the highest position throughout save at the end of the second cycle, when it occupied the sixth. Abscissa 6 twice occupied the first position, and never above the fourth. Abscissa 0 twice occupied the sixth position, and never below the fourth. Abscissa 3 seemed to hold a median position throughout.

Eleven per cent of the total successes possess the characteristic of having been given erroneously as responses to test syllables, previously to their being given in the correct position. These responses, when appearing in the correct position, usually elicited long times, the average time being 10934σ. It is very probable that this long average time arose from the inhibitive influence occasioned by having given the syllable in response to a previous test syllable.

It might be suggested that the long average time was due to some few very long unnatural times, due to chance occurrences. In order to throw light upon this point a table is

presented showing the distribution of the responses according to their time length.

TABLE XII

Work	0	1	2	3	4	5	6
$T < 1000$	1	1				1	
1000 < T < 2000	13	9	12	6	16	9	8
2000 < T < 3000	8	9	6	11	4	12	11
3000 < T < 4000	11	3	9	5	5	4	7
4000 < T < 5000	1	3	5	3	6	4	3
5000 < T < 6000	3	1	3	5	3	1	1
6000 < T < 7000	2	2		3	2	3	2
7000 < T < 8000		3		4	2	1	2
8000 < T < 9000		1	2	1	1	2	2
9000 < T < 10000	1	1	2	1	2		3
10000 < T < 11000			1		1		
11000 < T < 12000	1	2	1		1		
12000 < T < 13000	1			2			
13000 < T < 14000	1	1			1	3	1
14000 < T < 15000	2	1	1	3	1	1	
15000 < T < 20000	1	2	2	2	3	3	1
20000 < T < 30000	5	3	1	2	2	4	1
30000 < T < 40000	1					2	1

The arrangement is self-explanatory. The number of long times is rather large, except in case of abscissae 6 and 2, to be disregarded on the basis of unnaturalness. Abscissae 6 and 2, if considered in isolation, may appear to give weight to this idea. To be sure, for adequate comparison of the numbers under different abscissae, the total number for each point should be the same. However, the difference is slight, and if we correct the table to a standard of 50 as a total, proportionately to the present distribution, the correcting figure would in no case exceed 2, usually, not approaching 2 save in one or two cases under each abscissa. Bearing this correction in mind, we note that for $T < 2000\sigma$ the order of the abscissae, according to brevity of time, is 4, 0, 2, 1, 5, 6, 3. For $T < 3000\sigma$, this order is 1, 6, 5, 0, $\frac{2}{4}$, 3. $T < 4000\sigma$, 0, 6, 2, 1, 5, 4, 3. $T < 5000\sigma$, 2, 6, 0, 4, 5, 1, 3.

Plotting a curve for all those times less than 4000σ and another curve for all those times less than 3000σ we obtain the following, Figs. 6 and 7:

The curves fluctuate about the horizontal. This fluctuation is exceedingly slight. The maximum difference obtainable between two points in the curve of Figs. 6 is 283σ , in the curve

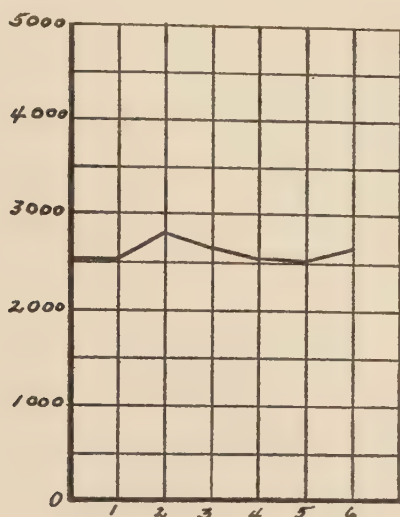


FIG. 6

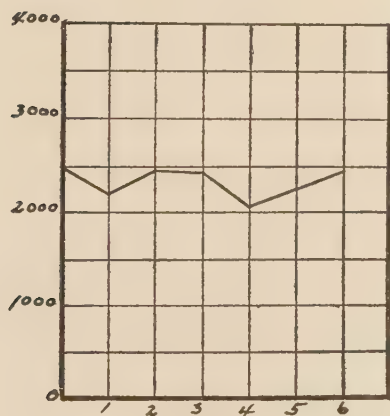


FIG. 7

of Fig. 7, 406 σ . According to the general conception of retroactive inhibition, the present time curves, as well as the general time curve, should gradually rise as the abscissae increase. We find no such tendency unquestionably manifesting itself. The curve of Fig. 6 ends at abscissa 6, 134 σ higher than its starting point. The curve of Fig. 7 ends 20 σ lower than its starting point.

Z. B. was experienced in learning nonsense syllables. It can

not be said that her learning of them was free from sense associations, yet she was not given to consistently forming them as an aid in remembering the syllables. Occasionally it was noticed that an associated (sense) syllable gave quite a long reaction time. In such cases the mental process seemed to be something like this: The subject recalled that in the learning there was a sense association connected with the test syllable but, somehow, it had dropped out, and time was consumed in search for the sense association. Sometimes the mere fact of an established sense association would lead to an incorrect response. The association would work but, due to its sense relation, might give some word that would fit the association just as well. In a few instances it was noted that sense associations, established during learning, did not consciously work for the recall, even though the correct response was given. Whether the sense association worked as a subliminal mediate association, or whether the pure association was strong enough to recall the correct response, cannot be definitely stated.

The subject thought she noticed variation in the different series of syllables with respect to the difficulty of learning them, characterizing some as hard and some as comparatively easy.

The subject was repeatedly questioned relative to any noticeable influence of the interpolated work upon the learned syllables. Characteristic responses are, "Noticed no influence of the work," "Didn't notice influence of work." Sometimes the subject would be surprised at the result at the end of the test, having expected to give a greater (or less) number of correct responses.

In cases when most, or a very few, of the responses were correct, the subject was questioned for any apparent reason for such a result. None was apparent. In the only case where all the responses were correctly given, W. O, R. 15, the subject characterized the result as a "Happy accident."

There were comparatively few recurrences of measures in the variant interval, an average of about one for every two series learned. The majority of these occurred during the variant

interval R. 15, or in the rest period previous to any work engaged in. As many recurred with R. 15 as recurred in the first rest interval of all the other five positions, where work followed a short rest period. About one-third of the recurrences came in the rest period following work. Only two measures and one isolated syllable are reported as having recurred during the work period. The measures reported as recurring almost invariably gave rise to correct responses in the test. Three instances are recorded to the contrary. These three recurred in the rest period following work. It may be said that there is slight evidence in favor of the view that the advantage shown by the R. type over the W. 6, R. 9 type was not due to the retroactive effect, in the latter case, but due to cutting off a few additional repetitions of some of the measures by the work introduced, while in the former case, a few additional repetitions went on unhindered. A consciousness of any such tendency towards a continuance of the repetition of the syllables, immediately after the learning process, was denied by the subject. In fact, the subject's opinion was that the syllables became a kind of nonentity during the rest period, the syllables, *per se*, not having any thing particularly attractive about them, tended to drop out of mind, while necessarily the mind wandered into easy channels of thought.

The number of successful responses for the first and seventh positions was, for R. 0, W. 6, 9 and 6 respectively; for R. 6, W. 0, 5 and 13. This appears slightly in favor of the view just referred to. When the remaining experiments, subsequent as well as foregoing, are considered in this respect, the seventh position usually has a tendency to give a few more results with rest than with work immediately following the learning. This tendency, however, is not sufficiently great to point to the interference by the work with additional subliminal repetitions as being more than a secondary factor, or otherwise as one of several primary factors, in explaining the difference at hand.

EXPERIMENT IX (b)

This experiment is a combination of Experiment IX (a), with the same subject. Two variations, however, are introduced; one with respect to the variant interval, the other with respect to the kind of work used in the variant interval. The subject either rested the whole of the variant interval, or she worked six minutes and rested nine minutes before testing. The work, in the latter case, came immediately after the learning of a series. The comparison series was learned and tested after fifteen minutes rest. On one day the series with work following was learned and tested first, on the next day the comparison series was given the first place. Cross-multiplication was no longer used as mental activity for producing the retroactive effect upon a learned series. For the work, or mental activity, the subject was given a problem to solve. Such problems were used as one would class as of the recreation type. A new problem was given each day.

The experiment continued eight experiment days, with the following results, Table XIII, $n = 56$:

TABLE XIII

	S_3	r	m.v.	%	S_2	S_1	T_r	$T < 2000\sigma$	$T < 1500\sigma$
Cs. I. Rest 15	30	3.67	1.5	53.6	3	3	5238	11	5
Cs. II. Work 6, Rest 9...	26	3.25	.94	46.4	2	4	5593	4	0

We again note a slight advantage in favor of R. 15. With the greater number of successful responses is correlated a shorter average reaction time. With the exception of the greater m. v. for Case I, the results point towards a slightly injurious effect of the mental activity following the learning of a series.

If we consider the first four experiment days, the number of successes for Case I and for Case II are 17 and 13 respectively. For the last four experiment days the corresponding figures are 13 and 13, thereby indicating that the whole disadvantage of Case II appeared in the first group of four experiment days, and was not equally distributed throughout the whole eight days.

Table XIV is presented for further considerations.

TABLE XIV

A Series											
D	W	R	D--	Di-	-i-	-it	--t	D-t	S ₃	S ₂	S ₁
1	6	9		1					4	1	
2	0	15		1					5	1	
3	6	9			2				1		2
4	0	15							6		
5	6	9			1				4		1
6	0	15			1				2		1
7	6	9							3		
8	0	15				1			6	1	
				2	4	1			31	3	4
B Series											
D	W	R	D--	Di-	-i-	-it	--t	D-t	S ₃	S ₂	S ₁
1	0	15							3		
2	6	9		1					4	1	
3	0	15			2				3		2
4	6	9							4		
5	0	15							1		
6	6	9			1				2		1
7	0	15		1					4	1	
8	6	9	1						4		1
			1	2	3				25	2	4

Comment upon this table is scarcely necessary, since it conforms with the results shown in Table X. Consequently, the discussion presented in connection with Table X is applicable to the present table.

If we now combine the present results with those of Experiment IX (a), we greatly increase the comparative figures for the two cases, viz., (1) learning, rest fifteen minutes, test and (2) learning, work six minutes, rest nine minutes, test. We thereby obtain comparative results for the two cases when $n = 196$. The different magnitudes appear in Table XV.

TABLE XV

	S ₃	%	T _r
Cs. I. Rest 15.....	88	55.7	6382
Cs. II. Work 6, Rest 9.....	70	44.3	5667

In five of the seven cycles, four results each, of the combined results, the number of successes for R. 15 slightly exceeds that for R. 0, W. 6, R. 9.

From the introspective side little can be added. The subject reported that she did not notice any inhibitive effect of the mental activity engaged in after learning a series. She was of the opinion that the new kind of material used for mental

activity did not noticeably command her attention more than the cross-multiplication.

EXPERIMENT X

The general plan of this experiment was the same as that of Experiment IX; ten repetitions were used. There intervened between the learning and the test of each series of syllables fifteen minutes, the last nine of which were always spent as a rest period. In the first six minutes cross-multiplication, as interpolated work, was introduced, the amount varying with the cyclic order as already outlined. Two series were learned on each experiment day.

After one and one-half cycles the subject, A., could spare no more time for the work. The experiment closed with $n = 42$, or six tests for each point of the six minutes varied. The results are presented below in Table XVI:

TABLE XVI

		S_s	T_r
Rest 0,	work 6, rest 9.....	15	1249
" 1,	" 5, " 9.....	17	2196
" 2,	" 4, " 9.....	19	1762
" 3,	" 3, " 9.....	18	2451
" 4,	" 2, " 9.....	23	1762
" 5,	" 1, " 9.....	12	1689
" 6,	" 0, " 9.....	14	2500

The first column contains the disposition of the variant interval. Corresponding to this, the second column contains the total number of successes, and the third column contains the average time for the correct responses.

The experiment was not carried to sufficient length to permit of great stress upon the results obtained. However, it seems apparent that there is no trace of a tendency towards the appearance of retroactive inhibition. In fact, we should infer that a modicum of work aids in producing a large number of successes. A peculiar departure exists in that with the most (least) work the average time appears the shortest (longest).

It should be mentioned that A. could scarcely avoid sense associations to connect the two syllables of a measure. Indeed, it was the exception, rather than the general rule, for him to

get a correct response that had no sense connection with its paired syllable.

EXPERIMENT XI

P. served as subject for the present experiment. The general plan is the same as that of Experiment III; eight repetitions were used. The length of the variant interval was fifteen minutes. A comparison was planned between only two conditions, between results obtained when no work was used in the variant interval, and those obtained when the variant interval was thus disposed: Immediately after learning, ten minutes work, followed by five minutes rest. The work used was playing chess. The operator had the chess-men in position previous to the learning of a set of syllables, that were to be followed by work, so that the play might begin without delay. Two sets of syllables were learned and tested on each experiment day. At least five minutes intervened between the close of the test of the first set and the beginning of the learning of the second set. On one day the experiment began with the work type, on the next day with the rest type. The experiment continued ten experiment days with the following results, Table XVII, $n = 70$:

TABLE XVII

		S_1	r	m.v.	%	S_2	S_1	T_r	$T < 1500\sigma$
Cs. I.	Rest 15.....	28	2.8	1.44	40	9	11	2343	14
Cs. II.	Chess 10; Rest 5....	35	3.5	1.10	50	9	6	2392	10

In the light of the explanation of the previous tables, the symbols used above require no further explanation.

Here extraordinary results appear overbalancing the scale in favor of Case II. The m. v. of Case II is slightly less than that of Case I. The average time of the successful responses is 49 σ longer for Case II than for Case I. Case II is slightly favored in the number of successes giving time less than 1500 σ .

In the present experiment the time factor gives—and then very meagrely—the only possible indication of the deleterious influence of retroactive inhibition. The number of successes— unquestionably the deciding criterion—instead of lending weight to such an influence of retroactive inhibition, distinctly nullifies

its possibility. In the opinion of the writer, the advantage shown by Case II is not to be interpreted as showing that the procedure of Case II is the more productive of successes in general. It seems that this advantage finds sufficient explanation in terms of chance variation in the syllables, experimental method, etc.

Relatively to the work used, it may be remarked that there occurs to the writer no mental employment that holds the attention more slavishly than does the game of chess.

EXPERIMENT XII

It will be remembered that in all of our previous experiments only experienced subjects were used. From a consideration of the possibility that subjects, inexperienced in learning nonsense syllables, might show quite different results from those shown by experienced subjects, the present experiment consisted in carrying out the previously adopted general plan with 34—11 women, 23 men—laboratory students, inexperienced in learning nonsense syllables. Each subject served two experiment days. Two tests were given him on each experiment day. Seven-measure syllables, two syllables to the measure, were given twelve repetitions for each subject. The variant interval—fifteen minutes—found distribution into two types, a rest (R.) type, consisting in rest throughout the variant interval; and a work (W.) type, consisting in working six minutes immediately following the learning of a set of syllables, then resting the remaining nine minutes of the variant interval. The work used was three problems of the recreation type.

The subjects were informed concerning the experiment only sufficiently to enable them to carry out their part of the experiment. At no time was it hinted that the operator's problem dealt with retroactive inhibition, or the comparison of results following work and rest. Several had the idea that some test of their memory was being made. The subject did not know, until the end of the learning process, whether he was to work or rest. The operator informed him at the beginning that he (the operator) would give him a signal, either "Work" or "Rest." In the case of "Rest" being given, he was to abstain

from any particular mental thought; in case of "Work," he should turn over the previously prepared sheet of problems, select one of the three and work hard until the signal for stopping was given. The sheet of paper, containing the three problems written on one side and the title "Problems" written on the other, was placed, with the written problems down, in easy reach of the subject. A sheet containing three problems different from those used the first experiment day was used for the second experiment day.

The two experiment days of each subject were separated by no constant time interval. It was considered necessary for each subject to maintain the same hour of the day in his two experiment days. This was departed from in only three instances, and then the displacement was only one hour.

In order to maintain an equal footing for each of the two types (R. and W.), seventeen of the subjects began their first experiment day with the R. type; and seventeen with the W. type. Those beginning the first day with the R. (W.) type began the second day with the W (R.) type.

The results obtained are abridged in Tables XVIII (a), XVIII (b), and XVIII (c) following:

TABLE XVIII (a)

No.	D.	Type R				Type W			
		S ₁	S ₂	S ₃	T _r	S ₁	S ₂	S ₃	T _r
1.....	W		5	7	1848	1	2	7	3175
2.....	R		1	10	2432			6	2317
3.....	R	1		5	2739	1		6	7739
4.....	R	1	3	6	1180	2		5	1099
5.....	W		1	9	1285	4	2	6	1830
6.....	W	1		6	4939	1		7	2173
7.....	R	1	1	5	2818	1	1	6	1380
8.....	R		2	12	1856		2	10	1747
9.....	R	2	2	5	1059			5	4308
10.....	R		1	9	1397	1		8	1317
11.....	R	3	2	5	1873	1	1	10	1806
T. G. A.		9	18	79	2120	12	8	76	2232

TABLE XVIII (b)

No.	D.	Type R				Type W			
		S ₁	S ₂	S ₃	T _r	S ₁	S ₂	S ₃	T _r
1.....	R	1	2	8	1231	2	1	7	1086
2.....	W	1		6	0830	1		6	0916
3.....	R	1	2	3	0906	2	2	1	?
4.....	W			10	2993		2	10	1348
5.....	W		2	5	2329			5	2707
6.....	W		1	6	2670	2	1	4	1968
7.....	W	2	1	5	0742			7	1326
8.....	W	1		10	1680	1		7	1502
9.....	W	2	3	6	1636		3	6	1849
10.....	R	3	1	2	?	2	1	2	4922
11.....	W	2	3		?	2	2	2	1737
12.....	R	2	1	3	1187	2	1	2	?
13.....	W		1	3	1922		1	6	1102
14.....	R	1	1	6	2620		2	4	10471
15.....	W	2		4	0787	3	1	5	1057
16.....	R		1	5	1377		3	4	0862
17.....	R	3		1	3948				
18.....	R	1	1	8	2689		2	10	1644
19.....	W	1	3	6	2546			11	2156
20.....	R	1	1	4	1710	2	1	3	4697
21.....	W	1	2	5	1332			10	1433
22.....	W	1	1	6	1587	2	1	6	1764
23.....	W		1	11	3062	1	5	6	1700
T. G. A.		26	28	123	2002	22	29	124	1969

TABLE XVIII (c)

Comb. T. G. A.....	Type R.				Type W.			
	S ₁	S ₂	S ₃	T _r	S ₁	S ₂	S ₃	T _r
	35	46	202	2047	32	37	200	2184

Table XVIII (a) shows the results for the eleven women. Table XVIII (b) gives the results for the twenty-three men. In the column D. is to be found the type—whether R. (rest) or W. (work)—beginning the first experiment day. T. G. A. = Totals and General Average, the latter referring to the time only. In Table XVIII (c) the results of Tables XVIII (a) and XVIII (b) are briefly combined. Under T_r is found the average time, obtained by totalling the times for the successful responses for the R. (or W.) type and dividing by the number of successful responses.

It is obvious that the results of any particular subject, considered alone, are of little value. However, when the results of the different experiments are considered in relation to each other, or *in toto*, it may be possible to approach some general conclusion. We reverse the order and deal with the latter first.

First. The total number of successes for the R. type was

202, that for the W. type was 200. There exists a difference, wholly insignificant. The average time shows a slight increase—137 σ —in type W. over that of type R. If we glance at the time results of XVIII (b) we note that No. 14 apparently gives a “freak” result, with respect to the W. type, in that it is so far different from any other average obtained. If we neglect the results of No. 14, our average, *in toto*, for the R. type is 2029 σ , and for the W. type, 1983 σ . This modified form appears more nearly correct, otherwise one result, decidedly outside the limit of variation, would exert too great a determining influence upon our comparative averages. It appears then that we may say, from the standpoint of the results considered *in toto*, neither the number of successes nor the average time is indicative of any deleterious influence of retroactive inhibition.

Secondly. If we consider the different results in relation to each other, we find the following. Of the thirty-four subjects there are fourteen, each of whom gives more successes for the R. type than for the W. type. There are twelve, each of whom gives more successes for the W. type than for the R. type. Eight of the thirty-four are neutral. This seems adequate proof that there is no general tendency towards favoring either type. Further, with respect to time, sixteen of the thirty-four subjects, give their average time for the W. type less than that for their R. type. Thirteen of the thirty-four subjects give their average time for the W. type longer than that for the R. type. Five of the thirty-four are unable to be compared. These facts of time make more certain the correctness of our modification introduced in the preceding paragraph. Again, we may say, when the results are considered in relation to each other, that neither the number of subjects favoring the R. type over the W. type, nor the number giving shorter times for their successful responses with the R. type than with the W. type, is indicative of any deleterious effect of retroactive inhibition.

EXPERIMENT XIII

The present experiment is a departure from the previous experiments, both as to method and as to apparatus. We may

designate the method as of the Reconstruction type. The apparatus consisted of a chess-board, five distinct chess-men (a pawn, a knight, a bishop, a rook, and a queen), a piece of cardboard 51 x 62 cm., and a stop-watch.

The chess-board was placed upon a table. The subject, Z. B., sat at one side of the table; the operator stood at the other. The operator placed five chess-men upon different squares of the chess-board, and took a record of their position. During this arrangement the piece of cardboard rested on the table, on the long side as a base, between the chess-board and the subject's eyes, preventing the subject from seeing the position of the chess-men. The cardboard was raised and the subject allowed fifteen seconds to study the different positions of the different men. After the fifteen seconds exposure, the cardboard was replaced in its previous position and the men were removed by the operator and placed in a convenient place for the subject to get. The cardboard was then laid over the face of the chess-board. The three minutes immediately following the closure of the exposing process, found disposition in two general types, a rest (R.), and a work (W.) type. The R. type consisted in the subject's doing nothing for the three minutes. The W. type consisted in the subject's working two minutes and resting one minute. For the first eight days the work consisted in the addition of columns of figures; for the last four days simple arithmetical problems were used, a new one being given each required time. Three minutes after the end of the exposure process, the cardboard was removed from the chess-board for the reconstruction, by the subject, of the previous positions occupied by the different chess-men. The time required by the subject for the reconstruction, was taken with the stop-watch. After the reconstruction the cardboard was replaced in its position between the subject and the chess-board, and the reconstructed position of the men recorded by the operator. The experiment was then repeated. At least three minutes rest was allowed the subject between the closure of the reconstruction and the beginning of the second experiment. On any experiment day six tests were

made. The R. and W. types alternated on any particular day. The first three days began with the R. type, the next three began with the W. type, the next three with the R. type, and the last three with the W. type. The experiment continued twelve experiment days, giving thirty-six tests for the R. and thirty-six tests for the W. type.

The errors in the reconstructed forms, and the time, were computed and tabulated. The error value for any chess-man, in the reconstructed form, was obtained, speaking mathematically, by adding the differences between the ordinates and the abscissae in the two cases, chess-board squares considered as units. To illustrate, a piece originally placed at b4 (German chess notation), and in the reconstruction, placed at g2, would give rise to an error value of $5 + 2$ or 7 for the particular piece. The errors for the five men were totalled, and this total was considered the error value of the test.

The results of the experiment follow in Table XIX:

TABLE XIX

		R. Type		W. Type	
		E.	T.	E.	T.
1.....	R	31	265	38	192
2.....	R	13	135	54	232
3.....	R	33	220	26	197
4.....	W	29	209	24	117
5.....	W	34	146	38	259
6.....	W	59	142	44	169
7.....	R	43	294	20	152
8.....	R	24	92	27	102
9.....	R	36	204	41	150
10.....	W	29	174	28	194
11.....	W	18	191	41	209
12.....	W	24	151	41	279
Totals.....		373	2223	422	2252
Av.		10.4	67.4	11.7	66.2
M.v.		5.6		6.0	

The first column gives the number of the experiment day and the type of test with which the work began on that day. Under R. Type and W. Type are given the errors, in sub-column E., and time, under sub-column T.; the figures given represent the total of the three tests of similar type for the experiment day opposite which the particular figures appear.

The difference between the averages for the two cases is so

small as to be wholly non-significant, while the m. v. is non-indicative.

In the reconstruction here required of the subject, we are dealing not merely with the impressibility aspect, but with the subject's ability to hold in mind an ordered system. This retention of systematic order is doubtless one of man's last acquirements in his mental evolution, and considered from the aspect of perseveration, appears to be one of the first to drop out. Consequently we might expect retroactive inhibition, assuming its existence, so much the more to manifest itself when dealing with this apparently unstable mental phenomenon. From the results at hand such, however, is not the case.

G. GENERAL DISCUSSION

In dealing with the individual experiments we have partially discussed the results obtained. A systematic unification remains to be accomplished.

Knowing the conditions set by an experimenter, his results place all who care to consider them upon a fairly equal basis. The domain of results gives way to that of interpretation, from which standpoint divergent lines may be taken by different interpreters. It is in this field of interpretation that the scientist, though in a sense "driven by the facts", in another sense, "moulds his own laws and makes his own conclusions."

To the writer it seems unquestionable, from the results presented in this paper, that too much stress has hitherto been laid upon the effect of retroactive inhibition. That there is such a thing as retroactive inhibition we are not wholly prepared to deny. Our results seem to justify the statement—and this is our main THESIS—*That retroactive inhibition plays a significant part in influencing the recall of nonsense syllables, appears exceedingly doubtful.* The tentativeness of our position follows necessarily from the considerations already presented. Exhaustive experiments are necessary before generalities can be indulged in if, indeed, generalities are ever permissible in dealing with mental phenomena.

It may be suggested that our results, and consequent con-

clusions, conflict with the accepted view of the working of the Perseveration Tendency, which, indeed, is one of the essential units upon which the theoretical argument for the existence and explanation of retroactive inhibition is based. Müller and Pilzecker appear to have thought of the nature of the perseveration tendency as a kind of after-discharge—a continued activity—of the nerve elements following any learning activity. The physiological work of Sherrington¹ on the spinal cord and the work on inhibition by Shepard² indicate that the after-discharge of nerve elements is definitely inhibited by any neural activity taking place during this after-discharge. From the standpoint of the greater value of divided repetitions as compared with accumulated repetitions the perseveration tendency as such seems definitely established. Our results leave retroactive inhibition questionable. The logical consequence, then, is that the nature of the perseveration tendency, which leads to the setting of associations, is not that of an after-discharge.

Again, it seems that hitherto emphasis has been laid upon retroactive inhibition as an inhibition presenting a single aspect—and that inhibitory. The work of both Sherrington and Shepard seems to indicate that inhibition is not a single-phased process. According to these investigators two processes giving rise to inhibition mutually inhibit each other; neither can inhibit the other without itself being subject to inhibition. If retroactive inhibition is to be conceived as according with this idea of the double aspect of inhibition in general, then we should expect the learning of a *Hauptreihe* to inhibit the learning of a *Nachreihe* as well as the learning of a *Nachreihe* to inhibit the preceding *Hauptreihe*. Consequently, against the conception of retroactive inhibition as of a single aspect—and this is probably the conception of Müller and Pilzecker—there may be urged two arguments, (1) the difficulty of the conception of a one-sided inhibition, and (2) the results of the present work, which do not necessarily require the assumption of retroactive inhibition at all.

¹ *The Integrative Action of the Nervous System*, 1906.

² *Psychological Review*, Vol. XX, No. 4, July, 1913.

We have tended to ascribe most of the differences between the comparison and the main series to chance variation. It may be claimed—and rightly—that chance variation should give evidence against as often as for retroactive inhibition. Considering our experiments in their totality, the majority of them *slightly* favor a trace of retroactive inhibition. Whether this tendency of the majority is itself a variation further experiments may decide. At present, in the opinion of the writer, the validity of retroactive inhibition remains more or less questionable. If we assume a slight amount of retroactive inhibition it may still be explained as due to a tendency of the work to block the after-discharge of the just learned syllables. The nature of this blocking is a difficult question.

For the small amount of retroactive inhibition granted I may be permitted to suggest an explanation analagous to that existing for the transference of training. From the neurological standpoint, in the learning of a series of syllables, we may assume that a certain group of synapses, nerve cells, nerve paths, centres, etc., are involved. Immediately after the learning process the after-discharge continues for a short time, tending to set the associations between the just learned syllables. Any mental activity engaged in during this after-discharge, involving or partially involving the same neurological group, tends, more or less, to block the after-discharge, and gives rise to retroactive inhibition. Engagement in any mental activity, involving a new—so far as it is new—group of synapses, neurones, etc., would allow the setting process of the just excited group to proceed unhindered. The effect of retroactive inhibition would vary directly as the relative identity of the neurological groups concerned. It appears exceedingly plausible that any given group involved in learning nonsense syllables is a relatively restricted and, more or less, isolated one, scarcely involving the more intricate ramifications of the higher association paths and centres, and hence much less liable to be influenced by mental activity, involving the complexity of the higher centres and processes. Upon this view we should expect retroactive inhibition to appear more readily where material

similar to that learned is used for the interpolated work. Where the learning of nonsense syllables is followed by work of a different nature—a mathematical problem, for instance—the relative number of identical elements of the two groups may be so few, owing to the complexity of man's neurological system, that no appreciable retroactive effect is elicited.

The neurological explanation just presented seems sufficient where the deleterious effect of the work is slight but appears inadequate for the results of Müller and Pilzecker which were obtained by using additional nonsense syllables as the interpolated work. To the writer it appears that Effectual Inhibition, occasioned by merely increasing the number of syllables, may play the *decisive* part in lessening the percentage of successful responses in the recall of a Hauptreihe which has been followed by the learning of a Nachreihe. Probably in this way is to be explained the following quotation from Eleanor C. McC. Gamble's "A Study in Memorizing Various Materials by the Reconstruction Method."¹

"With G. retroactive inhibition was obvious. Each series [*i.e.* of smells, colors, nonsense syllables] was remembered fairly well until the next was given. That is to say, the subject could name hours afterwards the members of the last series given, and the associations involved would remain almost undisturbed for weeks. But as soon as a new series was given, the eraser (the subject actually visualized a blackboard eraser in this connection) was drawn over the old series. A 'smudge' might remain to make the new series illegible but the old one could no longer be read off."

In the opinion of the writer a similar explanation applies to Ebbinghaus'² attribution to retroactive inhibition of the extraordinary increase in the number of repetitions necessary for memorizing lists of syllables as the "memory span" is exceeded. To quote,

"Die einzelnen Associationen beeinträchtigen und lockern sich immer wieder durch *rückwirkende Hemmung*, und die

¹ *Psychological Review*, Monograph Sup. No. 43, 1909, p. 138.

² *Grundzüge der Psychologie*, 1902, S. 652.

Herstellung einer bestimmten Festigkeit erfordert mithin einen immer grösseren Arbeitsaufwand zur Überwindung dieser Störung, je höher die Zahl der hemmenden und gehemmten Glieder sich beläuft."

But, in the light of the present experiments, the writer does not feel disposed towards accepting, as a general conclusion, even a greater difference when a consideration of pictures is substituted for the *Nachreihe*. There seems little doubt that cross-multiplication involves the expenditure of at least as much—and very likely more—mental energy as the contemplation of landscape pictures. With the use of such work the only one of our experiments particularly favoring the results of Müller and Pilzecker is Experiment III, and in that experiment the results are much less "striking" than those obtained by Müller and Pilzecker. The same subject, however, in Experiment I gave the two lowest points (of 16 points) of the success curve with R. 15, W. 0, and in Experiment IV gave even more successes with R. 2, W. 13 than with R. 15, W. 0, though this latter point can have no particular weight against the results of Müller and Pilzecker, since their work with pictures extended no farther than two minutes after learning.

It might be argued that retroactive inhibition, expending its effect upon the rapidly descending part of the forgetting curve (as given by Ebbinghaus¹) may influence the relative number of successes relatively more after a lapse of eight minutes than after a lapse of fifteen minutes, thereby partially harmonizing our results with nonsense syllables with those of Müller and Pilzecker. Admitting the validity of some such argument, it appears extremely insufficient to explain the differences obtained. Even from the standpoint of reaction time we fail to agree with the German investigators. Some of our experiments harmonize with their time results, while others oppose. Seemingly, then, the only course open to us is to place the results of their *Versuchreihe* 35 in some such class as "Happy Accident," or question their saliency upon the basis of unnaturalness.

¹ *Über das Gedächtniss*, 1885, p. 203.

It can scarcely be maintained or denied that a subject's tendency or non-tendency towards the formation of sense associations is a determinant of the appearance or non-appearance of results indicative of retroactive inhibition. Subject B., whose tendency in this respect was marked in the preliminary experiments, though not particularly noticeable in the present work, is the only one giving fairly unquestionable results in favor of retroactive inhibition, and from the introspective side, it will be remembered, this subject stated that work had no influence: if he had a syllable, he had it. This, to be sure, had no significance further than that the subject noticed no particular influence of the work. Subject A. of Experiment X, whose tendency towards the formation of sense connections between the syllables was well known previous to the experiment, and appeared throughout the experiment, gave results inharmonious with the assumed deleterious effect of retroactive inhibition. Our other subjects, it may be said, had no particular tendency in this respect, and not one of these gave results unquestionably in favor of the existence of retroactive inhibition. Argumentatively, from one standpoint at least, if retroactive inhibition is general in its effect, it would seem that of the two classes of subjects, those subjects possessing no particular tendency towards sense associations should show greater evidence of the presence of retroactive inhibition.

Doubtless it will have been noticed that the discussion has almost wholly neglected the results of Experiment VIII. As was mentioned previously, the fatigue element complicates these results and forbids their consideration in favor of retroactive inhibition.

Professor Pillsbury has indicated¹ the analogy between retroactive inhibition and the retrograde amnesia of the psychiatrist. In the case of the strong blow or emotional shock, it may be assumed that the effect is a general one and that the bonds, connecting the neurological groups, acting at the time with the remaining neurological groups, are severed. The events represented by this now isolated group are *forgotten* in the

¹ *Essentials of Psychology*, 1913, p. 196.

sense that they are not easily reached from the remaining neurological groups. That they are not wholly lost to the individual is shown by the fact that they may later return to consciousness, or, under suitable conditions, be reached. Interpolated work, it may be said, does not tend towards any such isolation of a group which has just been excited. Consequently, the fact that our results are not similar to those obtained by the psychiatrist, does not necessarily argue against their validity.

The number of partial responses is so small that we make no attempt to draw, from their distribution, any conclusion with respect to retroactive inhibition. We may mention that the average time for syllables, two letters correct, is much longer than that for wholly successful responses, and the average time for syllables, one letter correct, is still longer. Comparative results of a single experiment, Experiment IX (a), will suffice to show this difference, Table XX:

TABLE XX							
Work	0	I	2	3	4	5	6
S ₃	7039 (52)	6756 (42)	5625 (45)	6548 (48)	5967 (50)	7773 (50)	5706 (43)
S ₂	11982 (8)	15994 (5)	8843 (11)	13596 (15)	14951 (7)	10033 (11)	8596 (10)
S ₁	19610 (11)	19480 (9)	22849 (10)	23044 (12)	17684 (10)	21981 (14)	17406 (15)

The parenthesized figures represent the number of responses for which the adjacent figures are the average time.

H. SUMMARY AND CONCLUSIONS

The present work grew out of experiments conducted by Müller and Pilzecker, whose results showed decided evidence in favor of the deleterious influence, upon learned nonsense syllables, of learning a second series of syllables, or of observing and picturing to the operator landscape pictures immediately after the learning of the first series of syllables. Their experiment with pictures as interpolated work, showed slightly more decided results in favor of retroactive inhibition than did the experiments with a second series of syllables for the interpolated work.

Our work embraces a series of thirteen experiments, extending over a period of two school years and one summer.

The apparatus consisted of a modified form of the Wirth card-exposure apparatus, Hipp chronoscope, and subsidiary apparatus. In Experiment XIII a chess-board, men, and additional apparatus were used. Experiments I to XI and XIII were extended experiments with seven subjects. In Experiment XII thirty-four subjects were involved.

Series of fourteen nonsense syllables (save in Experiment XIII) were repeated in pairs a certain number of times. On each experiment day two series, an A and a B, were learned and tested, an interval of at least five minutes intervening between the work with the two series. The purpose of the experiments was a comparison between syllables learned with no interpolated work following, and syllables learned with work—usually cross-multiplication—variously distributed within the interval immediately following the learning process. The order of the syllables was changed, and after a definite interval, the first syllable of each measure was tested for the associated syllable. The response, reaction time, and introspections of the subject, were recorded. Experiment XIII approached the problem from the standpoint of reconstruction of positions of chess-men, where the studying, by the subject, of such positions was followed in one case by work, in another, by rest.

Experiment III is the only experiment giving results characteristically favoring the assumption of retroactive inhibition. The other experiments—Experiment VIII excepted—including our most extended one—Experiment IX—do not particularly speak for the existence of retroactive inhibition, either with respect to the number of successes, or the reaction time of the successful responses. Experiment XII, upon two counts, adds decided weight in favor of the non-existence of retroactive inhibition. Experiment XI militates decidedly against the assumption of retroactive inhibition. Hence we must needs suggest that the influence of retroactive inhibition is fairly unimportant and has been given too great prominence among psychological principles.

We may suggest the following conclusions as indicated, if not wholly proven, by the results of our experiments:

1. That retroactive inhibition plays a significant part in influencing the recall of nonsense syllables, either from the standpoint of the number of successes, or the length of the reaction time, or both, appears exceedingly doubtful.

2. No positive introspective evidence appeared in favor of retroactive inhibition.

3. With inexperienced subjects no evidence appeared in favor of retroactive inhibition, either from a combination of their results, or from a consideration of their comparative results.

4. A neurological explanation of a slight amount of retroactive inhibition is tentatively offered; Retroactive inhibition may present itself where relatively identical or partially identical groups of nerve centres, neurones, synapses, etc., are involved in learning the series of syllables and in the interpolated mental activity. As the neurone groups have relatively less and less in common, retroactive inhibition may manifest itself less and less.

5. From the standpoint of the position occupied in the learning, the seventh and first measures usually gave the largest number of successful responses.

6. The B series of syllables possessed a slight disadvantage as compared with the A series, probably due to a slight fatigue effect occasioned by the A series.

7. Different subjects showed no marked individual differences with respect to the manifestation of the effect of retroactive inhibition.

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